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Volume 3, Number 2, April 1982

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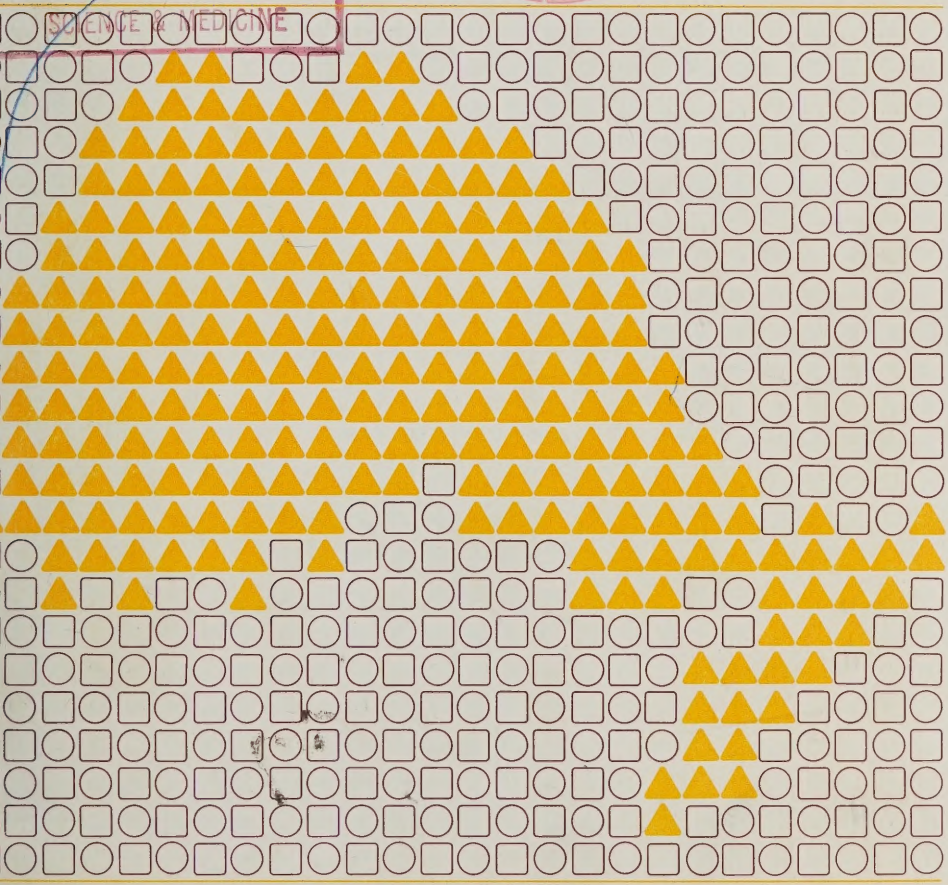
History of the Occupational Health Laboratory



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Additional copies of this publication may be obtained from the Ontario Government Bookstore, 880 Bay Street, Toronto, Ontario M7A 1N8. Price $1.50. Cheques or money orders should be made payable to the Treasurer of Ontario.

Occupational Health in Ontario

Volume 3, Number 2, April 1982

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Examples

1. Lee WR, and Miles S. Postgraduate preparation for occupational medicine. J Soc Occup Med 1976; 26:115-119.
2. Department of Health and Social Security. Notes on the diagnoses of occupational diseases, rev ed 1972; London HMSO.
3. Gamble JF, and Battigelli MC. Epidemiology. In: Clayton GD and Clayton FE. eds. Patty's industrial hygiene and toxicology. New York: McGraw Hill, 1978: Vol 1; 113-116.

Correspondence

To the Editor

We have recently received copies of Occupational Health in Ontario for October 1981 and as always we found the contents interesting and stimulating. I particularly enjoyed Donald Brown's review of respiratory protection, however, there are a couple of points arising from the article on which I would like to comment.

In listing the limitations of airline devices Mr. Brown states that they should not be used in IDLH atmospheres. He does not state, however, that most authorities permit use of airline respirators under IDLH conditions provided the respirator is fitted with a 5 minute escape bottle. Within Gulf Canada all airline units are so equipped.

In case history #8, relating to the problem of fitting of face masks on people with excess facial hair (beards, etc), we cannot accept the author's assertion that with pressure demand regulators a poor mask fit over facial hair is acceptable. In Gulf Canada we will not permit those operators whose duties require the use of respiratory protection, to wear excess facial hair in such a way that it will impede the seal of the mask. We are well aware of the human rights aspects of such a ruling, however, we feel it is essential to do all we can to ensure that any respiratory protection that we provide for our people will be used to maximum advantage.

We agree wholeheartedly with the message contained in case history #9, and the hygienist as well as plant supervisors and managers should conscientiously make the effort to set a good example by wearing whatever protection is required by plant and company regulations. Adequate signposting of all areas where identifiable hazards are likely to be encountered is also necessary.

I hope you find these few comments constructive and useful. We look forward to receiving further issues of your journal.

V.A. Barker
Director
Occupational Hygiene
Gulf Canada Limited.

Mr. Brown's response to Mr. Barker is printed below.

To the Editor

Mr. Barker's constructive comments are appreciated and, in reply, I would like to make the following points:

First, one of the basic limitations of airline respirators is that when used *alone* they should not be used in IDLH atmospheres. You are correct in stating that if an operator wearing an airline respirator is also equipped with a small air cylinder he is able to work in an IDLH atmosphere because he is able to escape the dangerous atmosphere in case the primary air supply is interrupted.

Secondly, with regard to facial hair, it is true that anyone who wears a respirator should, ideally, be clean shaven. However, if a person does have facial hair, the only way he is likely to have adequate protection is by wearing a respirator that ensures a positive pressure on the facepiece. There are many respirator types that can provide positive pressure on the facepiece. Examples include powered air purifying respirators, airline respirators operated on either continuous flow or pressure demand made, and finally, pressure demand self-contained breathing apparatus.

The purpose of case history #8 concerning facial hair was not to promote or suggest that facial hair is advisable. The point was to stress that if a person has facial hair, respirators providing positive pressure on the facepiece are the only devices that will likely give adequate protection. All negative pressure devices are completely unacceptable.

D.A. Brown

Douglas H. Harding, M.D.

Health Effects of Formaldehyde

Summary

The possibly erroneous idea that formaldehyde is a carcinogen is explained in this review. The argument is presented that this substance is an epigenetic carcinogen based on its irritancy and high reactivity. It is the irritancy and not the formaldehyde chemical that induces the chain of events leading to malignancy. The threshold for irritation of formaldehyde is 0.1 ppm, and if such a level were used to control exposure to the chemical, it would be expected that the danger from formaldehyde-induced cancer would be greatly reduced.

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Formaldehyde is a colourless gas with a pungent odour. The odour is a valuable property in that it warns of the presence of this chemical at reasonably low levels.

The gas is conveniently handled by dissolving it into water producing formalin, a 30 to 50 per cent by weight solution.

Human Exposure Potential

Formaldehyde is one of the most important industrial organic chemicals produced. It is used in the synthesis of other chemicals, mainly resins, and used directly in a wide variety of occupations such as those in hospitals, embalming, textile manufacture and agriculture. The resins are used mainly in the production of wood products, plastics and insulation.

Not only workers are potentially exposed, but individuals of all ages. The urea-formaldehyde resin has been used as foam insulation in homes, and is used in the glue in plywood, chipboard, particle board and fibreboard. The resin is the magic ingredient in textiles, producing their wrinkle-free, crease-resistant, permanent press qualities. Apparently, the urea-formaldehyde resin, in the presence of moisture and/or heat, breaks down to release formaldehyde and urea. This property is used to advantage in delayed release fertilizers where the urea is needed throughout the growing season. In homes, however, it is the release of the formaldehyde that is causing problems. The released urea can support the growth of molds, which may, themselves, initiate allergic reactions in the householders.

It has been noted that the presence of formaldehyde in people's homes and house-trail[1,2] has led to various health complaints usually related to the upper respiratory tract.

In passing, it should be noted that, for economic reasons during the production of wood products such as plywood and chipboard, the manufacturer may increase the amount of formaldehyde normally used, and thereby increase the rate of setting of the

adhesive. This allows an increase in the rate of the board manufacture, but the excess formaldehyde present will continue to evaporate over a long period of time amounting to several years. In England, such wood can be used only for certain types of construction.[2]

Formaldehyde is also found in the environment in photochemical smog, tobacco smoke, incinerator effluents and in automobile and diesel exhaust.[3,4]

Cigarette smoke contains as much as 40 ppm of formaldehyde by volume. It has been calculated from this that an individual who smokes a pack of cigarettes a day would inhale 0.38 mg, whereas occupational exposure to formaldehyde at three ppm could result in a daily intake of 29.0 mg.[5] The occupational dose is larger, but an argument is presented below suggesting that the cigarette smoker may be at greater risk.

Thresholds

The following thresholds were compiled from the literature:

0	- 0.05	ppm	—NAD
0.05	- 1.05	ppm	—Neurophysiological effect*
0.05	- 1.0	ppm	—odour threshold
0.05	- 2.0	ppm	—eye irritation
0.10	- 25	ppm	—upper airway irritation
5.0	- 30	ppm	—lower respiratory tract irritation
50	- 100	ppm	—pulmonary edema, pneumonitis
	100	ppm	—death

*e.g. lacrimation

Some Possible Sources

The following are possible sources of formaldehyde:
industrial processes
cigarette smoke (40 ppm or 0.4 mg/day body burden)
automotive exhaust
smog (photochemical)
incinerators
urea formaldehyde — in foam insulation
— in plywood and chipboard
— in permanent press, crease-resistant clothing

Concentrations in residences vary widely up to three ppm. The half life in resin-containing houses is 45 days to two years.

Metabolism

Formaldehyde is produced during the process of normal metabolism, but free formaldehyde is never formed. An enzyme exists, formaldehyde dehydrogenase, which removes hydrogen from formaldehyde. Injected formaldehyde is bound very rapidly to proteins with the free formaldehyde having a half life in plasma of less than one minute.

Absorption

Dose delivered to mucosa

Some interesting work has been done on the respiratory rate and the resulting dose delivered to the nasal mucosa. It was shown that repeated exposure to formaldehyde produced:

1. increased tidal volume in rats; and
2. decreased tidal volume in mice

The product of tidal volume X respiratory rate = minute volume; Minute volume gives the dose to rats and mice; Decreased tidal volume in mice plus decreased respiratory rate results in a lower dose being delivered to mice than to rats at a given concentration.

Researchers at CIIT[6] have succeeded in measuring the nasal cavity surface area by direct measurement. The dose delivered to the mice and rats can now be expressed in dose per unit of mucosal surface area. Preliminary results are as follows:

	Rat	Mouse
Formaldehyde concentration	18.4 μg/litre	18.4μg/litre
Minute volume	0.114 L/min.	0.012 L/min.
Nasal cavity surface area	13.66 cm^2	3.13 cm^2
Therefore, the dose is:	0.154 μg/min./cm^2	0.071 μg/min./cm^2

Even though the ambient concentration in the air is the same, the dose delivered to rats is about twice that for mice. A truer cause and effect dose rate can then be ascertained for irritation, mucous flow rate, metaplasia and carcinogenesis.

Radio-tagged Formaldehyde, Exposure Chamber Study

These experiments revealed several observations, as follows:

1. Most of the formaldehyde accumulates in the mucosa;
2. Cell replication, or turnover, increases markedly at 15 ppm;
3. Plasma levels were much lower than levels in the nasal mucosa;
4. The level in the respiratory tract falls rapidly with the distance from the nasal mucosa;
5. Organ levels were found to be unrelated to airborne concentration, and in major organs was about three times the plasma level.

Pharmacokinetic studies showed that excretion rates, as measured by CO_2 exhaled, had a fast phase for the first 12 hours followed by a slow phase. The excretion curves were the same for high or low concentrations, indicating that metabolism is independent of concentration and that there is no body buildup or storage. The half-life in plasma was found to be one minute for the free form. Airborne curves were similar to injection curves.

Following dermal application, less than three per cent of the dose applied appeared as CO_2 in exhaled air. It was also observed that a ring of yellow hair appeared around the site of application in rats. The ring expanded with time, indicating that the formaldehyde was evaporating and moving laterally through the fur. An estimate was made that 80 per cent of the applied dose was lost due to evaporation or reversible binding followed by evaporation. The remainder is thought to bind with proteins in the skin and so fails to reach the plasma.

Health Effects

There are three main toxic effects of formaldehyde being considered and these are its ability to cause 1) irritation; 2) sensitivity reactions; and 3) cancer. A good review of the subject is given by Kitchens, *et al.*[3]

1. Irritation

Irritation to mucous membranes is a well-known effect and has a threshold around 0.1 ppm. The TLV is presently set at two ppm (2.5 mg/m^3) as a ceiling value allegedly to protect workers from this irritation.

Reports[3,7] of industrial exposure of workers to formaldehyde describe such complaints as irritation of the eyes, respiratory tract and skin, disturbed sleep and unusual thirst on awakening at doses ranging from one to two ppm (1.3 to 2.5 mg/m^3). The irritation can express itself as itching eyes and dry sore throats. Some individuals appear to be more susceptible than others.

Irritation of the nasal mucosa causes stimulation of the trigeminal nerve, resulting in a painful burning sensation, rejection and a desire to withdraw, and a decrease in the rate of respiration. The trigeminal nerve also innervates the mucous membrane of the eye, and a referred sensation of burning of the eyes can also result. The decrease in respiratory rate produced by an irritant can be used in laboratory animals to quantitate the degree of irritation. The firing rate of the nerves involved can also be used.

Human Exposure

Volunteer human exposure, under controlled room conditions for short periods of time, indicates irritation of the eyes and nose at levels below the present TLV of two ppm. Complaints of discomfort increased with the dose, but some tolerance was seen after three hours.

The levels found for various effects on the respiratory system as determined by this experimental exposure of a few subjects are:

odour	0.05 ppm
eye irritation	0.01-1.2 ppm
nose irritation	0.05-1.2 ppm
throat irritation	0.05-2.1 ppm
lacrimation	0.05 ppm
slight discomfort	0.05-1.3 ppm
blinking	1.7 ppm
decreased mucous flow	0.1 ppm
increased mucous flow	1.3 ppm

2. Sensitivity Reactions

A small segment of the population may be especially sensitive to the effects of formaldehyde and may react in several different ways. These effects include asthma, mild persistent symptoms of the upper respiratory tract or various skin allergy syndromes.

The mechanism of sensitization is not known, but may be similar to that postulated for small reactive chemicals such as toluene-diisocyanate, in which it is thought that the small reactive chemical acts as a haptene and combines with a protein in the lung to

form an antigen, which, in turn, leads to the development of an asthmatic reaction.[8]

Although only four confirmed cases of asthma have been reported in the literature, it is expected that many cases are not reported.

Sakula[9] has reported the development of a late onset bronchial asthma related to formalin fume exposure in a pathology laboratory.

Hendrick[8] examined, in detail, the development of asthma in nurses exposed to formalin used to sterilize artificial kidney machines. Inhalation provocative tests using formaldehyde fumes induced attacks of wheezing in two nurses of the staff of 28. Six other nurses in this unit had developed similar symptoms since becoming exposed to formalin. Two of these six were tested with the inhalation provocative test, but did not respond. Reactions persisted for periods ranging from 10 hours to days, depending on the dose. The experimental dose level in these tests was a five to 15 minute inhalation of the fumes emanating from a 25 per cent solution of formalin. General good housekeeping in the renal unit reduced the incidence of attacks. The involved renal unit had poor ventilation. No asthma has been reported from other renal units. All of these exposure observations seem to indicate that a threshold level exists.

Surveys of embalmers[10,11] generally have shown some increase in symptoms of chronic bronchitis, including wheezing, in a small percentage, but no cases of asthma.

The second of these sensitivity reactions to formaldehyde is the development or revelation of a unique hypersensitivity in individuals exposed to the fumes.[3] The individuals complain of eye and upper respiratory tract irritation and of having a persistent mild cold. The patients have usually been living in a mobile trailer home, house or apartment in which construction of walls or cupboards have been of chipboard. Other persons do not react in the same situation. The patient improves when away from home but relapses after returning. The formaldehyde can evolve from the wooden surfaces for several years, often leading to a protracted illness until the diagnosis is made.

A survey[1] of 92 persons with this condition found the following symptoms most frequently noticed: irritation of the eyes, nose, respiratory tract, headache, nausea and drowsiness (sometimes described as lapse of memory).

Very low levels of formaldehyde are involved and the affected individual may have to seek a formaldehyde-free environment, often selling their houses or trailer-homes in order to do so.

Allergic dermatitis can develop from direct, as well as systemic, contact with formaldehyde. It may also develop following contact with formaldehyde resins in textiles.

3. Cancer

a) Mutagenesis

The mutagenic property of formaldehyde has been known from *in vitro* tests for several decades, but has never been confirmed in animal studies.

This has been demonstrated in several systems, which are listed below:

a) Magana-Schwencke[12] has studied the damage induced in the yeast Saccharomyces cerevisiae, and, in the reference, reports on the induction of single-strand breaks in DNA and their repair. He believes that formaldehyde is mutagenic in Saccharomyces cerevisiae.

b) Dickey[13] found formaldehyde to be mutagenic in Neurospora (the pink bread mold).

c) Nishioka[14] demonstrated the mutagenic effect of formaldehyde in E. coli. Rosenkranz, using an *in vitro* E. coli system in which these bacteria were deficient in DNA polymerase, found that formaldehyde reacted in the system as a carcinogen. He was convinced of the need to re-evaluate the continued universal use of formaldehyde, especially if exposure, even at low levels, is occurring over prolonged periods of time.

d) Nafei[15] produced mutations in Drosophila with formaldehyde. Several references are given by Wolf[16] showing that crossing-over also can be induced by formaldehyde in Drosophila.

e) Martin[17] found that formaldehyde could induce unscheduled DNA synthesis in a cell culture system using HELA cells.

Several experiments and reviews were presented concerning this aspect of formaldehyde toxicity at a recent conference[6] and are listed below.

It has lately been shown that formaldehyde increases sister chromatid exchange and unscheduled DNA synthesis.

There is a specific effect in fruit-flies, where only the males show a mutagenic effect and only when exposed during a certain stage of spermatogenesis.

Exposure of C3H/10T½ cells to formaldehyde alone, was negative, but in the presence of a promotor (TPA), numerous areas of cell transformation were seen, which were strongly dose-related. This finding is similar to the effects of UV light.

Other Tests

Ames Test	— negative up to 1000 μg/plate with and without S9 fraction.
Mouse Lymphoma Assay	— positive
CHO SCE Assay	— positive
CHO Aberration Assay	— negative
Cell Transformation Assay	— positive: 0.5 μg/ml without S9

The failure to confirm the mutagenicity findings of many short-term studies in animals is one of the problems in formaldehyde toxicity. This could be due to the animals' normal metabolic processes, which are capable of handling formaldehyde very quickly as a normal product of metabolism, as well as to the high reactivity of formaldehyde, causing it to bind with tissue constituents very shortly after entering the animal. Mutagenicity tests consisting of cells or bacteria in culture would not have such a high degree of protection. Such studies therefore make up an interesting side study of formaldehyde toxicity.

The door through which the formaldehyde must pass in order to induce a mutation may not exist in a living animal, since at too high a dose the cells are killed, while at too low a dose the cells are capable of handling the formaldehyde well. Since formaldehyde is very reactive, a high dose would be required if a small amount is to reach the DNA. This results in such a high degree of protein damage within the cell that the cell dies. Any formaldehyde reaching the DNA to induce mutations is after the fact. Research should be performed to ascertain if formaldehyde is reaching the DNA in cells that remain viable after exposure.

b) Carcinogenesis

William D. Kerns presented a paper at the CIIT conference[6] entitled 'Long-term Inhalation Toxicity and Carcinogenicity Studies of Formaldehyde in Rats and Mice'. He used Fischer 344 rats and

B6C3F1 mice, and divided them into groups of 110 animals/sex:
Dose: 0, 2, 6, 15 ppm inhalation levels;
Exposed 24 months at 6 hours/day, 5 days/week;

The death rate was significantly higher in the high dose group. Changes found appear to be more severe in rats than in mice at the same air level, but this could be an artifact in terms of dose delivered to the mucous membrane.

Findings

15 ppm: 93 of 240 rats developed anterior nasal squamous cell carcinoma;
2 of 240 mice developed anterior nasal squamous cell carcinoma;
Of the rats
4 also developed squamous papilloma;
3 also developed adenomatous polyps
2 also developed respiratory epithelial carcinoma

6 ppm: 2 rats developed squamous cell carcinoma;
1 rat developed respiratory epithelial carcinoma;

2 ppm: 5 rats developed adenomatous polyps

0 ppm: 1 rat developed adenomatous polyps.

Dose-related dysplasia and metaplasia developed before the carcinomas.

The lower respiratory tract showed dysplasia and metaplasia in high-dose rats, but no tumours were found.

At a dose of 15 ppm for four to six days, most of the respiratory cells are killed, with ulceration in both rats and mice. Repair is very rapid with squamous metaplasia, cellular proliferation and replacement with flattened cells. At 15 ppm, formaldehyde vapour causes increased cell turnover estimated to be at 70 times normal. Cell replication is an important factor relating to promotion of initiated cells. Two carcinogenic theories were discussed, one being that of a chemical carcinogen that binds with DNA to cause a mutation followed by proliferation or promotion to result in a neoplasm, and the other being that of an epigenetic carcinogen causing cellular damage at irritant levels followed by repair, which, if repeated, may eventually result in a neoplasm.

Other Animal Studies

Twenty-six week inhalation studies in monkeys, rats and hamsters for 22 hours per day, at 0, 0.2, 1, and 3 ppm, produced symptoms of irritation, such as hoarseness, congestion and nasal discharge, especially in high dose-groups. The pathology was negative except for the nasal turbinates examination, which showed, most notably at the high doses, squamous metaplasia, hyperplasia and basal cell hyperplasia in rats and monkeys.

The interpretation of *in vitro* results becomes uncertain when studies in animals fail to confirm the mutagenic findings in lower forms of life. The most significant of these uncertain experiments that have been reported in the literature is in the Japanese Journal of Cancer Research (GANN)[18], where it is reported that 65 weekly subcutaneous injections of a total dose amounting to 1300 mg/kg into rats resulted in a neoplastic response.

In an article by Hsie[19], Nettesheim is quoted from his 'unpublished results' as stating that formaldehyde is either carcinogenic or non-carcinogenic, depending on the means of exposure to the test animals.

A review of the literature by Migone[20] found formaldehyde to be a weak mutagen in micro-organisms, but not in mammals.

Horton[21] exposed C3H mice to the inhalation of gaseous formaldehyde at levels of 0.05, 0.10 and 0.20 mg/L for three one-hour periods each week for up to 64 weeks. No carcinomas were produced in the tracheo-bronchial tree. Basal cell hyperplasia and stratification, and some squamous cell metaplasia were noted. At the high dose level of 0.20 mg/L, these changes were found to be the greatest, with the additional finding of a typical metaplasia, but this level of exposure was too toxic to the mice, and had to be terminated before the 11th treatment.

Epigenetic Theory of Carcinogenesis

This theory attempts to explain carcinogenesis in terms of environmental influences affecting the genetic material to such an extent that the cell becomes malignant. It is a process comparable to cellular differentiation during development of the embryo to the adult. Differentiation is a mysterious process, but relates to the interplay between the genes and the environment.

The mutation theory of carcinogenesis states that a genetic change results in the transformation of a cell to a malignant cell and results in the growth of

tumour tissue, which appears to be permanent. This theory probably holds true for most kinds of tumours, but a few are better explained in terms of environmental changes.

The permanence of the malignant change, however, can be questioned since occasional cases of apparent reversion have been recorded in which malignant itssue has reverted to a normal or quasi-normal state.

Comparison of the Two Theories

Mutation Theory	Epigenetic Theory
1. Changes in the genes produce changes in the cytoplasm	Changes in the cytoplasm produce changes in the genes
2. No reversion should be seen	Miracle cures have been reported
3. Permanent cell change	Quasi-permanent
4. Cells multiply out of control of the body	Body out of control allowing cells to multiply
5. No threshold for the mutagenic agent is thought to exist	Threshold for the agent in the cell's environment exists

The pathogenisis of formaldehyde acting as an epigenetic carcinogen would be as follows:
The formaldehyde would rise in concentration to the point where normal protective systems would fail. The resulting environment would be detrimental to the cell's survival following penetration of the formaldehyde into the cells at rates greater than the cell can handle. Denatured cellular proteins would form resulting in changes within the cyptoplasm that eventually affect the nucleus. It is also possible that the cells are reacting to the noxious environment in some other fashion. Eventually, the genome expression is changed, i.e. the cell differentiates according to the new environment. In the case of formaldehydes, this altered differentiation consists of metaplasia. The metaplasia will exist as long as the environment remains altered, but eventually the expression of the genome becomes permanent or quasi-permanent. In the process of moving towards the new genome expression, some of the cells become malignant, perhaps by failure of the repression system.

The change in the environment of the cell can be continuous or episodic. Smokers are exposed to peaks of formaldehyde inhalation up to 40 ppm but their overall intake is relatively low. On the other hand, occupational exposure may result in a higher dose, but if this dose is evenly distributed over time, no harmful effects to the mucosa may occur.

The epigenetic nature of formaldehyde in causing squamous cell carcinoma of the nasal epithelium in rats and mice is supported by the following observations:

1. Formaldehyde creates a very strong irritating environment.
2. Formaldehyde causes considerable damage to cytoplasmic proteins of the cells and thereby influences the expression of genetic information.
3. The cells showed a marked response to the new environment by developing squamous metaplasia with marked hyperkeratosis and hyperplasia.
4. Levels of formaldehyde high enough to penetrate the cytoplasm to reach the nucleus and cause mutations would also be of such a strength to cause the death of the cell.

The possibility that formaldehyde is acting as a mutagen cannot be ruled out, however, because:

1. only two experiments involving rats and mice have been performed. There is a need to repeat the experiments and employ other animal species.
2. formaldehyde may be both an initiator and a promoter.

Other possibilities include a promoter effect of formaldehyde for other unknown carcinogens, say in the food supply or laboratory environment.

Finally, a virus infection in the colony may have influenced the development of cancer in these rodents. However, the expression of viral genetic information in a cell's genome is subject to the same forces as in the epigenetic theory.

Teratogenesis

Hurni[22] fed formaldehyde to beagles during their fourth to 56th day of gestation at dietary doses of 125 or 375 ppm (3.1 or 9.4 mg/kg body weight/day) and failed to affect the weight gain of the pregnant beagles, length of gestation or the size of the litters.

percentage of still-born pups, weight gain of the pups or survival to weaning. No internal or skeletal malformations were observed.

Four reports by different authors published by the Russians in 1968, 1968, 1972 and 1979 were reviewed and all were found to be evidentially insufficient for establishing teratogenesis due to formaldehyde.[6] The data could not be interpreted; the purity of the formaldehyde could not be established; the findings were subjective or the conclusions reached by the authors were not supported by the data in the paper.

A recent study, (Marks and Staples published in Teratology)[23] in rats, using doses varying from low to those that were lethal to the dams, has found no fetotoxicity and no malformations. The defects were looked for using a blind study method.

Epidemiology

An epidemiological study of West Virginia morticians gave no evidence that formaldehyde had an effect on the lower respiratory tract. A total of 105 morticians answered questionnaires, of which 99 underwent pulmonary function studies and 86 of these were matched according to their smoking history. Exposure averaged 0.8 ppm (1-1.5 ppm) formaldehyde during the embalming of a normal body. If the body had been autopsied, the exposure level reached 0.9 ppm (0-2 ppm). An embalmer normally handles 75 bodies a year, of which 15 are autopsy cases.

A proportionate mortality study among deceased New York morticians having had an estimated exposure to formaldehyde in funeral homes of 0.1 to 5.3 ppm, was unable to identify anything significant. Observations made were a slight increase of cancer mortality, arteriosclerotic heart disease, and accidents, and a decrease in pneumonia. No nasal or upper respiratory tract cancer was found.

A proportionate mortality study of 150 formaldehyde-exposed, deceased workers of Monsanto Co., at Springfield, Massachusetts, concluded that no conclusions were possible due to uncertainty of exposure and the small size of the sample. No trends were revealed that could be related to formaldehyde exposure.

A similar study of 136 deaths in a second formaldehyde manufacturing plant also failed to find significant trends in the causes of death.

An epidemiological study of morticians in Ontario is presently being conducted by Dr. R. Levine, Chief Epidemiologist, CIIT, Research Triangle Park, North Carolina.

Conclusion

Three main toxic effects of formaldehyde have been considered. These are its ability to cause (1) irritation, (2) sensitization, and (3) cancer. Irritation to mucous membranes is a well-known effect and has a threshold around 0.1 ppm. The present TLV has been set at two ppm as a ceiling value ostensibly to protect workers from this irritation. Sensitization occurs in a few individuals who may become quite sensitive to the presence of formaldehyde in the air or in contact with their skin. The symptoms developed are similar to a mild upper respiratory infection or are similar to contact dermatitis in cases where the skin is in contact with the formaldehyde. Very low levels are involved and the affected individual may have to seek a formaldehyde-free environment, often selling their houses or trailer-homes in order to do so.

The ability of formaldehyde to cause squamous cell carcinoma of the mucosal lining of the nasal turbinates in rats and mice has been a recent discovery. Concentrations of six and 15 ppm in air, administered to rats and mice over a two-year period was able to induce, first, hyperplasia and squamous metaplasia of the mucosa, followed by the development of invasive squamous cell carcinoma. Although not conclusive, an argument is presented to support the contention that formaldehyde is acting mainly as an epigenetic carcinogen. It is argued that only a remote possibility exists for this substance to act as a mutational carcinogen. To further strengthen the epigenetic mechanism in this case, studies should be initiated to detect formaldehyde-DNA adducts, and to explore the promoter property of formaldehyde. The original work should also be repeated after taking precautions to eliminate other carcinogens and viral infections.

These two systems differ significantly, with epigenetic carcinogens having a threshold level to cause neoplasia, while those chemicals that act directly, or via a metabolic pathway, on the DNA, are considered to have no threshold level. The latter case, then, requires the statistical calculation of risk assessment to arrive at a socially acceptable level of risk.

I have concluded that the level of formaldehyde necessary to cause mucous membrane irritation and injury should also be the threshold for its ability to cause cancer of the mucous membranes exposed to it. Please note that it is the irritation that is carcinogenic, and that irritation is a universal phenomenon found in all animals. The findings in the rats and mice are therefore much more significant than they would be if formaldehyde were a mutational carcinogen.

Epidemiological studies to date have not shown an increased incidence of cancer in persons repeatedly exposed to formaldehyde.

Individuals who are hypersensitive to the substance generally cannot find relief from their symptoms unless they remove themselves from exposure. Attempts to purge formaldehyde from a house or trailer-home usually end in failure.

An average concentration of formaldehyde set at the threshold level for upper respiratory tract irritation should protect individuals from any potential carcinogenic properties of this chemical. Since the upper respiratory tract irritation threshold is reported to be 0.1 ppm, it is suggested that this level would be suitable to provide the required protection.

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Liquid Industrial Waste Disposal in Ontario

Summary

This paper reviews the current literature and reports on field visits made to determine if an occupational health hazard exists in the disposal of industrial waste.

The field visits were conducted to gather information on the work environment, facilities and work practices since the work force involved has recently been brought under the administration of the Occupational Health and Safety Act.

A potential for exposure exists; however, it is of an acute nature rather than long term. Recommendations are made to increase the awareness of workers involved and avoid unnecessary exposure.

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Introduction

The major functions of the Ministry of the Environment (MOE) in relation to the waste disposal operations are:[1]

a) to provide information on the selection, development and closure of sites:
b) to advise operators on sound management practices:
c) to assist in upgrading operations to meet the requirements of legislation.

The Ministry of Labour is concerned with workers' health and safety.

The *Occupational Health and Safety Act* extended coverage to all those who work at landfill sites or other waste disposal facilities. However, since the responsibility for health and safety of the operators at landfill sites accepting liquid industrial waste has only recently come under the jurisdiction of the Ministry of Labour, very little was known about workers' possible exposure to airborne contaminants. The purpose of this study was, therefore, to gather information on the work environment and work practices at these landfills. Information was also gathered on experiences in the United States.

United States Experience

The new public alarm has been generated mainly by the vigorous efforts of the news media. Almost on a regular basis, stories of improper disposal of waste are flashed across television screens and reported in the lead articles of major newspapers and magazines. Not surprisingly, these stories are usually based on experiences in the United States.

Recent instances concerning liquid industrial waste in the US include:[2,3,4] Love Canal; a Rhode Island pig farm; a disposal site that exploded in Elizabeth, New Jersey; an abandoned sand and gravel mine in Connecticut; the Valley of the Drums,

(where 17,000 drums littered a seven-acre site in Kentucky with some 6,000 drums full, many of them oozing their toxic contents on the ground), and an open pit disposal site in Louisiana. The US Environmental Protection Agency has estimated[5,6] that tens of millions of tons of hazardous waste are disposed of annually, and that about 94,000 landfills and 173,000 surface impoundments, pits, ponds and lagoons are used for waste disposal. Only limited data, however, are available on the extent of land disposal and the locations used for hazardous substances. This, in spite of the fact that it is the most common disposal method and, in many states, it is the predominant one. The number of closed and abandoned sites is also not known.

The United States has experienced major problems[6] because of the lack of federal and state legislation, the relative surplus of land and water and the nature of the free market economy. This has permitted generators of hazardous waste to dispose of their residues in the least costly manner. These methods included:[7]

i) disposal into unregulated landfills (many of them poorly designed and sited),
ii) disposal in on-site pits, ponds, or lagoons (often without proper sealing),
iii) unmonitored and uncontrolled incineration.

Perhaps the most dramatic and highly publicized example of inadequate disposal of hazardous chemical wastes occurred near Niagara Falls, New York.[8] More than 200 families living along an abandoned waste disposal site, known as Love Canal, had to permanently evacuate their homes when toxic chemicals seeped up through the ground and into the basements. The more than 20,000 metric tonnes of chemical wastes in Love Canal contain an estimated 300 different chemicals, 100 of which have been identified to date. New York state officials estimate that possibly 10 per cent of the chemicals in the dumpsite may be mutagens or carcinogens. Benzene, a known carcinogen, as well as 11 other suspected carcinogens, has been identified. One of the wastes at the site, trichlorophenol, contains dioxin, a highly toxic substance. Investigators report that there may be as much as 500 pounds of dioxin buried in Niagara County.

NIOSH Study

Because of the recent increased public awareness of the hazards from liquid industrial waste, there have been many investigations into the consequences of improper waste disposal. These studies have been concerned almost exclusively with the effects on the environment (water pollution) and the citizens of the nearby community. While the public certainly has a reason to be concerned, it appears that their concern has overshadowed that of the workers at the sites.

The National Institute for Occupational Safety and Health in the United States assessed worker exposure at hazardous waste sites. In a paper presented by Costello and Kominsky[9] at the Society for Occupational and Environmental Health Hazardous Waste Conference, Washington, DC, December 8-10 1980, the following findings or conclusions were given:

1) that occupational exposure monitoring at hazardous waste sites must consider both chronic and acute exposures, routine as well as emergency responses and geographically related facilities as well as on-site monitoring. This logically extends to community monitoring of non-occupationally exposed populations.
2) that occupational exposure at waste sites can vary with the physical condition of the site. Dust and the materials associated with dust are suppressed during wet conditions, and exposure levels rise when the site dries out. Volatiles, of course, may increase or decrease with fluctuations in temperature.
3) that exposure by the skin route may well be as important as exposure by inhalation.
4) that most of the acute hazardous waste site incidents observed have followed the improper use of protective respiratory equipment.

Acute Worker Exposure

The published literature detailing the chronic effects of worker exposure to chemicals at landfill sites is essentially non-existent. However, there have been two tragic incidents when exposure to toxic chemicals caused death.

A truck driver was killed in 1978[2,10] as he discharged waste from his truck into an open pit at a disposal site in Ilberville Parish, Louisiana. He was asphyxiated by hydrogen sulphide produced when liquid wastes mixed in the open pit. The problem arose because toxic wastes from dozens of indus-

tries in Louisiana, Texas and elsewhere were being dumped indiscriminately with neither safety equipment being used nor orderly procedures being practised at the facility.

The flaws in Britain's system of disposal of dangerous waste materials were tragically illustrated by the death of a lorry-driver who was poisoned by vapours from Britain's biggest waste disposal facility at Pitsea, Essex.

Ironically, the fact that Pitsea has so many advantages as a dump actually increases some of the risks. The site's main advantage is that it has a thick underlay of clay, which geologists say makes it almost 100 per cent certain that chemicals cannot seep away into the Essex water supplies. British industry takes advantage of the site's suitability to dump a vast amount of waste material there, (70 million gallons of industrial waste in one year).

The accident occurred when a load of sulphuric acid (harmless enough by Pitsea standards) ended up in the wrong part of the tip and was discharged into a slit trench that already contained polysulphide waste. The two chemicals reacted to produce hydrogen sulphide. The driver was quickly overcome, and died before he reached hospital.

Ontario does not have the same degree of hazardous waste problems as experienced in the United States for the following reasons:

1. The chemical industry in the US is much older and produces many more chemicals.
2. The US chemical industry is much more complex. There are many jobbing companies that get a contract from a big chemical company to make a hazardous chemical. The small jobbing company may close down after a few years and leave tank trucks and drums of hazardous chemicals behind. We don't generally have this problem in Ontario.

When the big boom began in the early 1970s, the MOE introduced legislation to control landfill sites.

Liquid Industrial Waste in Ontario

On January 20, 1981, Dr. Harry C. Parrott, DDS, the then Minister of the Environment, in a speech to the Standing Committee on Resources Development of the Ontario Legislature, reviewed the accomplishments of Ontario in handling liquid industrial wastes and the problems that lie ahead.[11]

In 1967, an attempt was made to determine the amounts of liquid industrial wastes in Toronto. The estimates were crude and uncertain as there was no reliable knowledge of the amounts arising from industries outside Toronto.

In 1971, the first serious attempts to determine the sources, amounts and methods of disposal were undertaken by the newly formed Waste Management Branch of the MOE in spite of the fact that there was absolutely no public interest in the treatment of hauled industrial waste at that time.

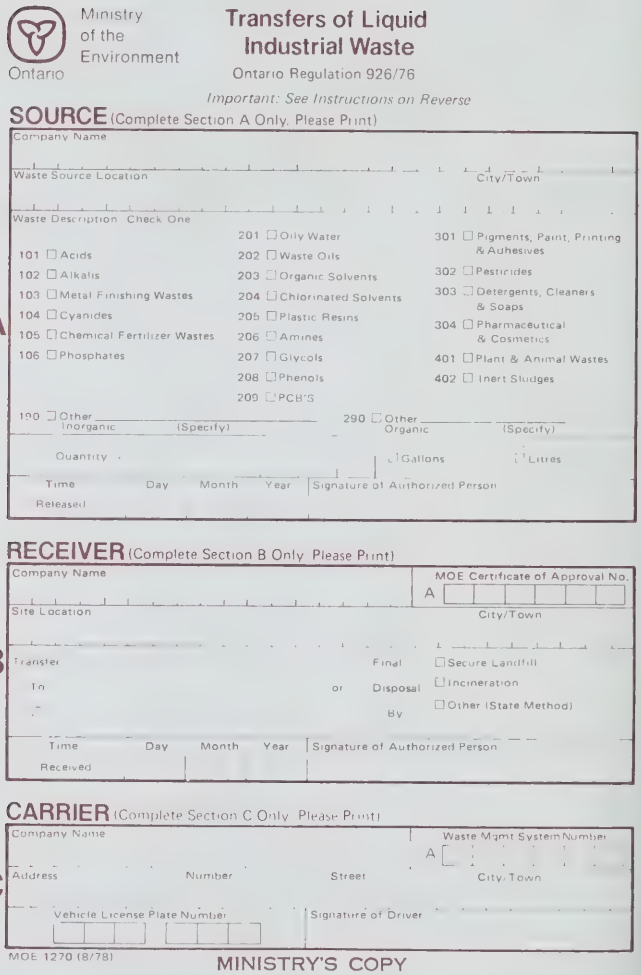
There has since been a growing repugnance for the practice of disposing of untreated liquid waste into municipal dump sites; and by the mid '70s public interest and concern raced ahead of technical knowledge and ability to treat all wastes. Ontario took the lead in Canada with the provision of treatment plants at TDS Company in Hamilton, (1975), and the TRICIL operation at Mississauga (1973).

A liquid incinerator was established by the Goodfellow Disposal Company in 1965 at Corunna, which was purchased by TRICIL in 1973. These facilities had a limited range of treatment capability and in 1977 the plants in Hamilton and Mississauga were subsequently closed down, largely on economic grounds.

A short while later, attempts were made to develop a deep well disposal in Canboro and a waste treatment facility in Nanticoke. Both attempts foundered in a sea of public opposition. About the same time, the TRICIL operation at Corunna was improving its techniques so as to avoid offending its neighbours and to modernize its treatment capabilities.

Meanwhile, the MOE was continuing to try and develop a system that would clearly identify the amounts, types, sources and destinations of industrial wastes that are hauled by trucks for treatment and disposal. This was, and still is, a first in Canada, but unfortunately, there has been little information of value in the United States to give guidance in this undertaking. The current way-bill regulation of notification stemmed from these origins. The way-bill regulation is clearly the key to proper accounting in an industry whose limits are ill-defined. The use of way-bills was made mandatory in April 1977. (See sample form). In conjunction with the way-bill there is a Waste Classification Guide (Appendix A).[12] This groups liquid industrial wastes to assist identification and disposal.

Figure 1 **Sample of Way-bill Form**



Ministry of the Environment
Ontario

Transfers of Liquid Industrial Waste
Ontario Regulation 926/76

Important: See Instructions on Reverse

SOURCE (Complete Section A Only. Please Print)

A

Company Name

Waste Source Location — City/Town

Waste Description Check One

101 ☐ Acids
102 ☐ Alkalis
103 ☐ Metal Finishing Wastes
104 ☐ Cyanides
105 ☐ Chemical Fertilizer Wastes
106 ☐ Phosphates
201 ☐ Oily Water
202 ☐ Waste Oils
203 ☐ Organic Solvents
204 ☐ Chlorinated Solvents
205 ☐ Plastic Resins
206 ☐ Amines
207 ☐ Glycols
208 ☐ Phenols
209 ☐ PCB'S
301 ☐ Pigments, Paint, Printing & Adhesives
302 ☐ Pesticides
303 ☐ Detergents, Cleaners & Soaps
304 ☐ Pharmaceutical & Cosmetics
401 ☐ Plant & Animal Wastes
402 ☐ Inert Sludges
199 ☐ Other Inorganic (Specify)
299 ☐ Other Organic (Specify)

Quantity ☐ Gallons ☐ Litres

Time Released — Day — Month — Year — Signature of Authorized Person

RECEIVER (Complete Section B Only. Please Print)

B

Company Name — MOE Certificate of Approval No. A

Site Location — City/Town

Transfer To — or — Final Disposal By
☐ Secure Landfill
☐ Incineration
☐ Other (State Method)

Time Received — Day — Month — Year — Signature of Authorized Person

CARRIER (Complete Section C Only. Please Print)

C

Company Name — Waste Mgmt System Number A

Address — Number — Street — City/Town

Vehicle License Plate Number — Signature of Driver

MOE 1270 (8/78)

MINISTRY'S COPY

Under the way-bill regulation,[13] the hauler may dispose only at an approved waste disposal site or at an approved sewage works if the owner of the sewage works consents. The hauler must also provide a partially completed way-bill to the generator of the waste and to the receiving waste disposal site. Finally, the operator of the site receiving the waste must submit a copy of the way-bill to the ministry and keep a copy for a year.

The industry producing the waste and the operator of the site receiving the waste are responsible for recording, on the way-bill, the description and amount of the waste, the time of the transfer and other details to be filled in. Non-compliance with the regulation is an offence, rendering the offender subject to a fine of up to $2,000 per day.

The Ministry of the Environment worked on both long and short-term liquid industrial waste and hazardous waste management plans, but some of the short-term plans ran into difficulties as shown by the following examples.

i) *Mississauga*
As far back as 1976, the Ministry of the Environment undertook test work for burning PCBs. However, the City of Mississauga passed a bylaw prohibiting the burning of PCBs in 1979.

ii) *Ajax*
The Region of Durham supported studies to look into the feasibility of converting a sewage treatment plant, soon to be redundant, into a facility for treating industrial waste. Although a consulting engineering firm confirmed the idea was sound, public opposition was such that the Region of Durham decided to stop the proposed conversion.

iii) *Thorold*
This site near St. Catharines was considered for a solidification facility. As soon as details of the proposal were revealed, the citizens echoed the familiar concern, so the proposal was dropped.

In view of these adverse developments, the Ministry of the Environment decided to develop a site itself: so in November 1980 it announced plans for a proposed government facility that would meet most, if not all, of the criteria suggested by the consultants and would be close to some of Ontario's biggest

generators of industrial waste. The area was not heavily populated, and as most of the land required already belonged to the government, no requisition was required.

The need for this type of facility was urgent since it had been clearly established that landfilling of untreated industrial waste was not acceptable and would eventually be stopped. This is illustrated by the fact that in 1979 there were over 20 landfill sites accepting untreated liquid waste. At the beginning of 1981, there were 11 sites. Now there are only nine sites and the number may further decrease.

The Proposed Government Facility[14]

It was proposed that the facility would be run by a newly formed corporation with a board of directors composed of two representatives of the general public, two members of the local community, two technical experts and a chairman appointed by the government.

To ensure the excellence of the facility, the Government of Ontario was prepared to commit 60 million dollars. The technologies that were to be considered included the following:

1) Solidification Plant,
2) Secure Landfill. This would be used to hold the inert material from the solidification plant. There would be no deposition of untreated waste into the landfill. This facility would cover 50-60 acres with an anticipated life span of 20 years.
3) Incineration,
4) Degregation Facility (bug pond),
5) Deep Well injection of treated waste.

This facility was proposed for a site at Cayuga. However, later studies revealed faults in the geographical strata and the site was declared unsuitable. An alternative site is being sought.

Present Situation

At a recent symposium on The Treatment and Disposal of Hazardous Wastes May 7 and 8th, 1981 in Toronto, Macfarlane[15] presented an excellent review of the present problem of liquid industrial waste in Ontario.

There are, at present about 60 million gallons of liquid wastes per year, ranging from oily wastes through fertilizers and phosphates to cyanides and PCBs. A tabulated list of 'Quantities of Liquid Industrial Wastes Generated in Ontario', from January to December 1979 is given in Appendix B (com-

piled by the Ministry of the Environment from information listed on way bills). Approximately one-tenth of these wastes are dangerous. None are suitable for municipal sewage treatment plants because they will upset the microbiological activity upon which the treatment system depends or because the treatment itself will be inadequate to detoxify the wastes.

While the figure of 60 million gallons of liquid industrial waste per year seems large, it is small compared to non-industrial liquid waste. In Toronto alone, 275 million gallons of sewage go for treatment each day.

The most widely adopted disposal method for liquid industrial waste in all the provinces except Ontario is landfilling directly into municipal garbage. In some ways, it is difficult to demonstrate any ills that stem from this process, and experience in Ontario has shown that household wastes provide a rather efficient sponge. The major problem with this disposal method, however, is that nobody is sufficiently convinced that liquid wastes poured into garbage are destroyed or detoxified, although escape into the public environment has rarely been detected.

Once a suitable treatment facility is available (i.e. proposed government facility) the practice of landfilling liquid industrial waste should end in Ontario.

At the proposed government site the waste will be rendered harmless by a suitable alteration of chemical structure. The organics will be incinerated and it is probable that the inorganic liquids and sludges, after some preliminary treatment to bring them into proper condition, will be immobilized. They will be converted into a concrete-like material by mixing the liquid wastes with cements and landfilling in the ground.

This facility will permit industrial wastes to be consigned with a reasonable certainty that proper treatment will be applied. This may overcome some of the problems inherent in the present arrangements.

In Ontario, only those waste treatment and disposal processes or sites that have received a Certificate of Approval from the MOE may be used for the treatment and disposal of hauled liquid industrial wastes. Approved waste treatment and disposal processes can not be used to treat wastes other than those specified in the Approval.

Appendix C[16] lists the MOE recommended treatment and disposal processes for various categories of hauled liquid industrial wastes.

Site Survey Methodology

In this survey, all eleven landfill sites were visited, but it was discovered that two of the sites no longer accept liquid waste.

Before visiting each landfill, discussions were held with the regional MOE personnel. This served two useful purposes. Firstly, it was possible to gather background information as well as detailed information on types and quantities of waste going to the site. Secondly, it made the MOE aware that these landfill operators were now covered under the *Occupational Health and Safety Act*.

During the visits to the landfill sites the following information was gathered:

i) size of site
ii) number of workers
iii) duties of workers
iv) equipment used at site
v) sanitary facilities provided
vi) personal protective equipment provided to operators
vii) potential for operator exposure.

Results

The landfilling operations at the majority of the sites visited were very similar. In its simplest terms, landfilling is the dumping of waste onto the ground, compacting solid material and covering with cover material, which is usually sand or gravel. At most of the sites visited, the liquid industrial waste is dumped in with the solid waste. Typical machinery used is:

i) Euclid sand movers
ii) Compactors
iii) Bulldozers

While landfilling is a fairly basic operation and all the sites had many similarities, they varied in size, type of wastes handled, number of workers employed, degree to which the waste is checked prior to disposal and sanitary facilities provided.

Site A

This 41.6-hectare landfill is one of the two major sites that accept large and significant quantities of toxic industrial waste. This liquid waste is normally

brought in tank trucks rather than drums. A summary of the wastes is as follows:

Description	Quantity (gallons)
acids	12,600
metal finishing wastes	721,129
cyanides	900
phosphates	3,000
other inorganic	116,550
oily water	1,317,500
waste oils	23,180
organic solvents	74,000
plastic resins	3,015
pigments, paints, printing and adhesives	14,040
detergents, cleaners and soaps	33,850
inert sludges	253,045

The landfilling operation carried out at this location is different from normal landfilling. This is due to the fact that instead of the waste being merely dumped onto the ground, a pit or cell is actually dug out of the ground. A cell measures 300′ × 600′ × 30′ deep. Solid and liquid waste is added to the cell on a regular basis until the height of the waste reaches 6 ft. from the grade. From that point on, only solid waste is added and then cover material is applied. In general, there is no segregation of the waste and only one cell at a time is filled. However, when asbestos is received, it is placed in a small hole about 10′ × 14′ × 10′ deep and thus segregated from other solid waste.

Although there are no weigh scales, there is a full-time receptionist who keeps a record of the quantity of all waste entering the site for the purpose of charging the various industries and municipalities who bring waste to the site.

There are three landfilling operators and each is assigned to work with one of three types of machinery (sand mover, compactor or bulldozer).

Each of the landfilling operators is provided with adequate protective equipment.

A brick building provides administration and amenity facilities.

Every quarter there is a safety meeting in Windsor, at which the landfill operators and drivers meet with management. Films are shown and discussions are held about safety aspects of the job. There are, however, no discussions about occupational health hazards in handling and disposing of liquid industrial waste.

Site B

This landfill site contains an incinerator that incinerates liquid industrial waste. The solid waste is landfilled using the cell method. The only liquids that go to the landfill are acids, alkalies and bunker C oil. However, before these liquids are dumped into the cell, they are first mixed with four parts of fly ash. This is done by a back hoe.

The waste received is broken down into 21 different types of wastes including:

acids	amines
alkalies	glycols
metal finishing wastes	phenols
cyanides	other organic
chemical fertilizer waste	pigments
phosphates	pesticides
other inorganic	inert sludges
oily water	detergents
waste oils	pharmaceutical and
organic solvents	cosmetics
plastic resins	plant and animal waste

All liquid waste that comes to the site must be accompanied by a data sheet. There is a full-time gate operator who does not allow any trucks to enter unless the driver produces this information. If the driver does have the appropriate information, the truck proceeds to the off-loading area.

At this site there are 68 full-time employees.

At the off-loading station and in the maintenance shop, ablution and eating facilities are provided.

Site C

This 72-hectare site has an operator shack with a table and a portable toilet. The shack is heated in winter.

Five men are employed; two are assigned to landfilling and three to the equipment repair shop.

The following is a partial breakdown of the liquid waste brought to the site in 1980.

i) 130,000 gallons – inert sludge
ii) 30,000 gallons – metal finishing waste
iii) 85,000 gallons oily water
20,000 gallons – pigments, paints, printing and adhesive waste
10,000 gallons – detergents, cleaners and soaps.

About two trucks per week of treated sewage sludge are dumped into special lagoons. When this dries out in the summer, it is bulldozed onto the ground.

There is a natural leachate pond, which catches runoff from the landfill and which feeds into the river. There is also a liquid waste dumping pond.

Site D

This 81-hectare site has a weigh scale just inside the entrance, and all trucks carrying solid waste are weighed. The purpose is to keep a record of how much waste is coming in and to determine how fast the site is filling up.

Before any liquid waste is received at the site, it must first go to the city water pollution plant to verify that the liquid can be dumped at the site.

One full-time scaleman and three landfilling operators alternate on running the compactor, bulldozer and scraper.

A heated mobile trailer located near the dumping area contains lockers and lunch room, plus sanitary facilities with showers.

The main sources of liquid industrial waste include

i) 10,000 to 20,000 gallons wash water from mixing tanks
ii) 12,000 gallons of phosphates (wash water from cleaning operation)
iii) 6,000 gallons of latex paints (either off specification or clean out from mixers)

Some minor sources of liquid industrial waste include

i) plant and animal waste (more like manure than liquid)
ii) weak acid (raw acid isn't received unless there was a spill in an industry).
iii) organic waste

Site E

This 16-hectare landfill site is run by one operator who spends the majority of his time driving the bulldozer (with a cab that is enclosed but not pressurized), which is the main vehicle available. There is no weigh scale at the entrance and no special attention is given to check the waste that enters the site.

According to the records from 1980, the site received about 2 trucks per week containing sewage sludge from a local Ministry of Environment treatment plant, and about one truck per week of poultry waste.

Near the entrance, a barn contains sanitary facilities.

Site F

This 11.4 hectare site is operated 8 hours per day. There is a weigh scale just inside the entrance, and all vehicles, except those hauling residential garbage, are weighed. There is one full-time operator who records the weights. There are three landfilling operators and each is assigned to work with one of the three types of machinery (sand mover, compactor or bulldozer). It was noted that the cabs of the sand mover and compactor are enclosed and pressurized.

A brick building provides eating and washing facilities.

The operators are provided with protective clothing, but no respiratory equipment.

The main sources of liquid industrial waste include:

i) wash water from the mixing vats of a cosmetic company
ii) sludge from a tannery
iii) brewery waste

Site G

This 20-hectare landfilling site is located within a total site area of 36 hectares. The site operation is only intended for the receiving and disposal of the following categories of waste:

i) 80 per cent domestic
ii) 10 per cent commercial
iii) 5 per cent non-hazardous solid industrial
iv) 5 per cent hauled liquid industrial waste

The two main types of liquid industrial waste received are:

a) plastic resin
b) inert sludges

The majority of the industrial waste is mainly intermediate waste from polymer production. In most cases, the material is either off specification ABS, side products or material that hasn't fully reacted.

At the site there was a small wooden shack, but no sanitary or eating facilities for the workers.

Site H

This 8.1-hectare landfilling site is run by one operator who is not provided with any motorized vehicles. He spends the majority of his time directing the solid waste to the proper location and assisting some of the individuals in dumping their garbage.

Once every few weeks a front end loader arrives to dig a hole for the garbage and to cover it with soil.

The site operation is only intended for the disposal of the following categories of waste:

i) domestic
ii) commercial
iii) 5 per cent non-hazardous solid industrial
iv) 5 per cent other waste (limited to brush, lumber and construction debris)
v) 12 per cent hauled liquid industrial waste (limited to inert sludge)

All of the liquid industrial waste comes in the form of an inert sludge. This liquid is placed in either of two specially constructed lagoons, each measuring about 120′ × 30′ × 8′ deep.

Although these lagoons are not segregated from the rest of the landfill, there is a separate road, which has a separate locked fence. The sludge is merely discharged into the lagoon by the hauler and allowed to evaporate with time.

A shelter without washing facilities is available to the landfill operator.

Site I

This 9-hectare landfilling site is run by one operator who spends the majority of his time driving the bulldozer (with a cab that is enclosed but not pressurized), which is the only vehicle available. There is no weigh scale at the fenced entrance and no special attention is given to check the waste that enters the site.

According to the records, the site receives the following liquid industrial waste:

i) Pigments, paints and adhesives (class 301). This waste (about 1,500 gallons per month), which consists mainly of water, goes to the landfill.
ii) Oily water (class 201). This waste is spin finish, which is 95 per cent water. The rest of the waste, consisting of less than 5 per cent oil, comes from the production of nylon.
iii) Alkalies, which come from a plating operation at a rate of about 2,000 gallons per year. The liquid is actually spent acid that has first been neutralized and then made alkaline for disposal purposes.

When a truck comes in with liquid, the liquid is merely dumped onto the ground at the south corner of the site.

There is no shelter and no hygiene facilities for the operator at the site.

A dump truck is used to draw cover material from the pit at the site. The main duty of the landfill operator is to make sure the solid waste is covered every night. He has nothing to do with the liquid waste at all.

The liquid waste, which is dumped on the ground, is not covered with any gravel. The liquid waste dumping location was chosen because it is farthest from the ditch that gathers the run off.

Conclusion

Except at Site B (which is a unique operation involving incineration), the exposure potential of the landfill operators (where liquid industrial waste is handled) is very similar. It would appear that operator exposure to health hazards should be low, provided that good work practices are followed. This is due to the following factors:

i) under normal conditions, the operators are not manually handling any of the liquid waste.
ii) None of the operators are required to clean any of the trucks containing liquid waste.
iii) The vehicles in which the operators spend the majority of their time carrying out landfilling operations normally contain closed cabs.
iv) Except at Site A and Site B, the quantities of liquid industrial waste received is low.
v) Except for Site A and Site B, the toxicity of the liquids received is not that great. Usually, the chemicals are from washing operations as opposed to raw chemicals.
vi) When a tank truck carrying liquid waste comes to the site, the truck driver opens the valve to allow the liquid to run out onto the site. During this time, the landfilling operator may be at the other end of the site.

In spite of the points mentioned above, it should be emphasized that there is potential for worker exposure to health hazards for the following reasons:

i) At some of the sites, there is very little attention given to the waste that is received at the site. In other cases, there are full-time gatemen who record the waste that is brought in. However, even in these cases, the records show usually only weight or source rather than details of the contents.

ii) Except at Site B, none of the operators are given any details of the contents of the liquid waste they are handling. While the Ministry of the Environment does require the hauler to provide a weigh bill for all liquid industrial waste upon entering the site, it contains very limited information. The waste description is very general (i.e. acid, alkali, organic solvent, pigments, paints and adhesive). Obviously, a liquid containing one per cent acid will present little or no hazard while a liquid that contains 50 per cent acid may present a significant hazard, especially if skin contact occurs.

iii) At most sites, little or no personal protective equipment is made available to the worker.

iv) At most of the sites, the workers receive no information or training on the hazards of the materials they are working with. Thus, although at one site there are regular safety meetings, there are no discussions on health hazards.

v) While most of the liquid comes to the sites in tank trucks, in some cases, sealed drums are received. When the operator runs over drums of liquid waste, the drums are pierced by the prongs on the wheels, and liquid can squirt out.

vi) At some of the smaller sites, the sanitary facilities provided are rather poor. At these same sites, there are typically no lunchroom facilities.

Recommendations

The following recommendations are suggested to increase the awareness of workers involved and avoid unnecessary exposure.

1. Each landfill operator should be provided with a complete set of personal protective equipment, which should include:
   - impermeable gloves
   - impermeable suits to prevent skin contact
   - eye protection for both the toxic and mechanical hazards
   - suitable respiratory equipment (for vapour hazards)

2. Smoking and consumption of food and beverages should only be allowed in separate areas free from contamination after personal hygiene measures have been taken.
3. Good sanitary facilities should be available at the site. This should include an area for changing into work clothes, plus water for washing. Ideally,

there should be showers, flush toilets, running water and lockers. While it may be expensive and unnecessary to build a concrete building with these facilities, a mobile trailer, which seemed acceptable, was used at one site.

4. The operators should be informed of the risks to themselves and others, and should receive instruction and training not only in the safe handling, but in what to do in the event of an accident.
5. Every effort should be made to reduce fires at the landfill sites. As an example, hot ashes should not be permitted to be disposed of.
6. All liquid industrial waste should be accompanied by a safety data sheet that not only gives toxicity, but also personal protective equipment required for safe handling and emergency procedures.
7. Records should be kept of all liquid industrial waste material received at the site. These should include source, type, major composition of waste, quantity of waste and date received.

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Appendix A

Classification Guide for Hauled Liquid Industrial Waste

Class No.	Waste Description
101	**Acids**
	Sulphuric Acid
	Hydrochloric Acid
	Pickling Acid
	Pickle Liquor
	Stripping Solution
	Sulphonation Waste
	Low pH Waste
	Carbonate Waste
	Aluminum Chloride
	Acid Sludge
	Sulphate Sludge
	Acetic Acid
	Formic Acid
	Fatty Acids
	Phosphoric Acid
	Nitric Acid
102	**Alkalies**
	Caustic Solution
	Lye
	Soda
	Sodium Hydroxide
	Metal Cleaners
	Potash
	Ammonia
	Hydration Filtrate
	Bleaching Powder
	Aluminum Hydroxide
	Xanthelene (Alkali and Sulphur)
	Aluminux
	Lime Sludge
	Caustic Sludge
103	**Metal Finishing Wastes**
	Lead Chromate
	Zinc Chromate
	Chromic Acid
	Sodium Chromate
	Potassium Dichromate
	Chromium Sulphate
	Chromium Hydroxide
	Chromium Dioxide
	Chromium Sludge
	Zinc Plating Solution
	Zinc Hydroxide
	Zinc Sulphate
	Zinc Sludge
	Flux
	Nickel Plating Solution
	Nickel Sludge
	Brass Plating Solution
	Brass Pickle Acid
	Copper Plating Solution
104	**Cyanides**
	Sodium Cyanide
	Scrap Cyanide
	Stretford Liquor
	Cyanide Sludge
105	**Chemical Fertilizer Wastes**
106	**Phosphates**
	Bonderite
	Phosphate Sludge
	Phosphate Slurry
201	**Oily Water**
	Oil and Water
	Diesel Fuel and Water
	Gasoline and Water
	Tanker Washings
	Spine Finish Waste
	Interceptor/ Separator Waste
	Oil and VARSOL
	Coolants
	Slop Oil
	Tank Sludge
	Oil, Sand and Water
	Skimming Sludge
	Tar and Water
	Oily Sludge
	Pit Sludge
202	**Waste Oils**
	Used Oil
	Bunker Oil
	Crude Oil
	Kerosene
	Naphtha and Gas
	Asphalt
	Tars

Class No.	Waste Description
203	**Organic Solvents**
	Acetone
	Methyl Ethyl Ketone (MEK)
	Alcohols
	Thinner
	Methyl Hydrate
	Ketones
	Formaldehyde
	Cyclohexane
	Isopropyl Alcohol (IPA)
	Hexane
	Enamel Laquers
	Benzene
	Toluene
	Xylene
	Aromatic Hydrocarbons
	Styrene
	DOWTHERM
	Ethyl Benzene
	VARSOL
	Hexalene
204	**Chlorinated Solvents**
	Carbon Tetrachloride (CCl_4)
	Trichloroethylene
	Perchloroethylene
	Dry Cleaner's Solution
205	**Plastic Resins**
	Vinyl
	Acrylic Resin
	Plasticizers
	Polymerstyrene
	Polyethylene
	Polystyrene
	Acrylonitrile (ACN)
	Nylon Salt Solution
	Malic Anhydride
	Styrene Acrylonitrile (ABS)
	Methyl Methacrylate
	Varnish
	Polyvinyl Chloride (PVC)
	Latex
	Isoprene
206	**Amines**
	Amide
	Toluene Diamine (DA)
	Trimethylamine (TMA)
	Triethylamine
	Urea
	Alcanolamines
	Oxazolidone
	MEA
	DEA
	FLEXONE
	MONEX
207	**Glycols**
	Polyether Glycol
	Propylene Glycol
	Polyglycol
	Polypropelene Glycol (VORANOL)
	Antifreeze
	DR-I-Wash
208	**Phenols**
	TDI Residue
	Phenolic Oil
	Phenol and Water
209	**PCBs**
	PCB Liquid
	ASKAREL
	INERTEEN
	PYRDRAUL
301	**Pigments, Paints, Printing and Adhesives**
	Dye Solution
	Paint Solution
	Waste Ink
	Paint Sludge
	Wax and Water
	Rubber Cement
	Pigment Sludge/Slur
302	**Pesticides**
	Pesticide Solutions
	VITAVAX
303	**Detergents, Cleaners and Soap**
	Laundry Wastes
304	**Pharmaceutical and Cosmetics**

Class No.	Waste Description
*190	**Other Inorganic** (to be stated)
*290	**Other Organic** (to be stated)
401	**Plant and Animal Wastes**
	Fat and Water
	Lignin
	Glue Wastes
	Grease and Water
	Molasses
	Tallow
	Concentrated Flavours
	Bacterial Sludge
	Grain and Water
	Mash
	Protenaceous Sludge
	Food Wastes
	Vegetable Oils
	Tannery Wastes

Class No.	Waste Description
402	**Inert Sludges**
	Portland Cement
	Concrete Slurry
	Glazing Slurry
	Marble Sludge
	River Silt
	Carbon Black
	Metal Fines
	Clay Slurry
	Scrubber Water
	Scale
	Sand and Water
	Rock Wool
	Filter Backwash
	Silica
	Starch
	Titanium
	Plaster of Paris (Gypsum)
	Metalic Hydroxide Sludges (excluding chromium)

Interim Classification of Hazardous Wastes
601 Pathological
602 Explosive
603 Radioactive
604 Flammable
605 Volatile
606 Toxic
607 Others

*These are wastes not otherwise classified. If a particular waste description recurs a significant number of times, it will be included separately on the next printing of the guide.

Appendix B

Quantities of Liquid Industrial Wastes Generated in Ontario (Summary Report) January to December 1979

Waste Classification		Volume (gallons)
101	Acids	4,060,100
102	Alkalies	1,746,000
103	Metal Finishing Wastes	2,847,400
104	Cyanides	41,700
105	Chemical Fertilizer Wastes	641,100
106	Phosphates	262,000
190	Other (inorganic)	7,076,600
201	Oily Water	14,542,000
202	Waste Oils	2,477,000
203	Organic Solvents	2,839,200
204	Chlorinated Solvents	95,800
205	Plastic Resins	1,094,900
206	Amines	279,200
207	Glycols	421,600
208	Phenols	503,700
209	PCBs	14,600
290	Other (organic)	3,991,000
301	Pigments, Paint, Printing and Adhesives	3,184,300
302	Pesticides	216,000
303	Detergents, Cleaners and Soaps	402,000
304	Pharmaceutical and Cosmetics	22,000
401	Plant and Animal Waste	2,819,200
402	Inert Sludges	11,094,900
	Unspecified	874,000
Grand Total		61,547,100

Appendix C

Recommended Treatment and Disposal Methods

Waste Description	Waste Classification	Treatment and/or Disposal
A. Organic Wastes		
1. 'Rich' organic liquids	202-209	—recovery and re-use
	302-304	—reclamation
		—incineration
2. 'Lean' organic liquids	201-209	—recovery and re-use
	302-304	—reclamation
		—incineration
		—physical/chemical
		—biological
		—deep well disposal
		—wet air oxidation (WETOX)
		—solidification
3. Organic sludges and solids	202-209	—wet air oxidation (WETOX)
	301-304	—incineration
		—secure landfill
		—sludge farming
		—biological treatment
		—land disposal
4. Organic sludges—plant and animal based	401	—as in A(3)
		—land disposal
		—sanitary landfill (approval of MOE or owner required)

Waste Description	Waste Classification	Treatment and/or Disposal
B. Inorganic Wastes		
1. Inorganic liquids	101-106	—recovery and re-use —physical/chemical —deep well disposal —solidification
2. Inorganic sludges and solids	101-106	—solidification —secure landfill
3. Inert inorganic sludges and solids	402	—sanitary landfill (approval of MOE or owners required) —land disposal
C. Oil/Water Mixtures		
1. Oil and water	201	—emulsion breaking —oil separation —electrochemical
a) oil phase		—as for waste oil, D below
b) water phase		—as in A(2) —municipal sewer system
c) sludge phase		—incineration —solidification —sanitary landfill (approval of MOE or owner required) —land disposal
2. Oil interceptor and grit chamber clean out	201	—secure landfill —sanitary landfill (approval of MOE or owner required) —land disposal
D. Waste Oils		
	202	—recovery and re-use —reclamation —incineration —road oiling —fuel for cement kiln

Waste Description	Waste Classification	Treatment and/or Disposal
E. Special Wastes		
1. Caustic Phenolates and sulphides from petro-chemical processing	290	—reclamation —incineration —deep well disposal —chemical oxidation
2. Chromium hexavalent	103	—chemical reduction to trivalent state, then as in B(1) or B(2)
3. Cyanides	104	
a) solutions 100 ppm CN		—alkaline chlorination —electrochenical oxidation, then as in B(1) or discharge to municipal sewer —incineration
b) solids		—incineration —secure landfill
4. Halogenated organics	204 205 209 302 304 290	—incineration
5. Industrial brines	190	—deep well disposal —as recommended by MOE
6. Mercury and its salts	190	—solidification —secure landfill
7. Semi-metals and compounds — arsenic — antimony — boron — selenium	190	—secure landfill —solidification
8. Radioactive wastes		—to be reviewed with MOE and may be subject to Atomic Energy Control Board regulations
9. Tank truck washing wastes	(all)	—as recommended by MOE
10. Other wastes		—as recommended by MOE

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10 mm Nylon Cyclone Dust Sampler: A Critique

Summary

This paper briefly reviews the background material and the experimental work done on the application of the 10 mm nylon cyclone as a size-selective dust sampler. Size-selective characteristics of a metal cyclone designed to follow the BMRC size-selection curve are also discussed. Based on the pulmonary deposition data and other published work it would appear that a nylon cyclone conforming to the ACGIH size-selection curve provides a better estimate of dust hazard.

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The two criteria that have been widely used for respirable dust measurements are those of the British Medical Research Council (BMRC)[1] and the American Conference of Governmental Industrial Hygienists (ACGIH),[2] adopted from The Atomic Energy Commission (AEC) Los Alamos Conference.[3] The BMRC criterion is met by certain stacked parallel plate horizontal elutriator-type size selectors. The ACGIH size-selection curve is approximated by the use of a 10 mm cyclone.

Since its development by the US Health and Safety Laboratory (HASL) in 1960, the 10 mm cyclone has been extensively used in the USA as a size-selective dust sampler. Nylon cyclones are considerably smaller in size and weight than other size-selective devices, and are not seriously affected by orientation. These characteristics of the nylon cyclone are particularly useful in personal sampling. For many years, the 10 mm nylon cyclone, designed to conform to the ACGIH criterion, has been routinely used by the US Public Health Service as a size-selective presampler to remove the non-respirable fraction of the dust. It should be realized that during the development and trial runs of the nylon cyclone in the USA, a metal cyclone of comparable size and weight was also being developed in Britain. The most commonly used metal cyclone, designed by Higgins and Dewell,[4] conforming to the BMRC criterion, is manufactured by Casella, England. Both the samplers, nylon cyclone of ACGIH specifications and metal cyclone of BMRC criterion, have been used in Ontario mines for monitoring the pneumoconiosis-producing dusts. The Occupational Health Branch, on the other hand, had used only the 10 mm nylon cyclone.

Pulmonary Deposition and Respirable Mass Size-Selection Curves

As both the criteria, ACGIH and BRMC, are based on lung deposition data, it may be appropriate here to describe the pulmonary deposition curve and how it relates to the two sizedselector acceptance curves. For pneumoconiotic diseases, the only particles of pathological interest are those that penetrate to, and are deposited in, the pulmonary air spaces. The dust deposition studies have been carried out by two methods:

(a) Inhalation experiments, in which the concentration of particles of specific size is measured entering and leaving the respiratory system.

The BMRC curve corresponds approximately to lung deposition measured by inhalation methods.[5] Similarly, the AEC or ACGIH curve has been patterned more directly after Brown's respiratory tract deposition data.[6]

(b) By examination of the dust found in the lungs at post-mortem.

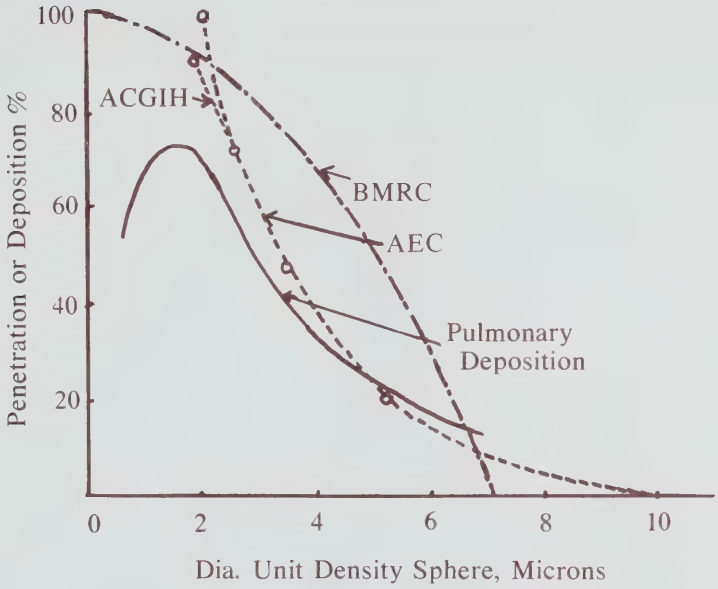
Post-mortem studies[7] in Britain have indicated that the dust found in the lungs of coal miners at death is appreciably finer than is suggested by the BMRC size-selection curve. It has therefore been questioned whether the 1952 recommendation[8] should be revised. More recent inhalation studies have also supported the earlier results by this method and hence, the difference between the data obtained by the two methods remain unresolved.[9]

In order to compare the BMRC and ACGIH size-selection curves in the light of pulmonary deposition data, the pulmonary deposition curve, along with the two size-selective curves, is shown in Figure 1.

The BMRC curve, in Figure 1, lies somewhat above the pulmonary deposition curve, and, in fact, was drawn to give a best fit between the calculated characteristics of an ideal horizontal elutriator and lung deposition data. As can be seen, the BMRC recommended curve is convex-shaped, in contrast to the concave shape of the experimental pulmonary deposition curve.[10]

An intercomparison of the three curves also clearly shows that compared to the BMRC size-selective curve, the concave shape of the ACGIH curve, lies much closer to the pulmonary deposition curve.

Figure 1 Comparison of Respirable Mass Sampler Acceptance Curves with the Pulmonary Deposition Curves



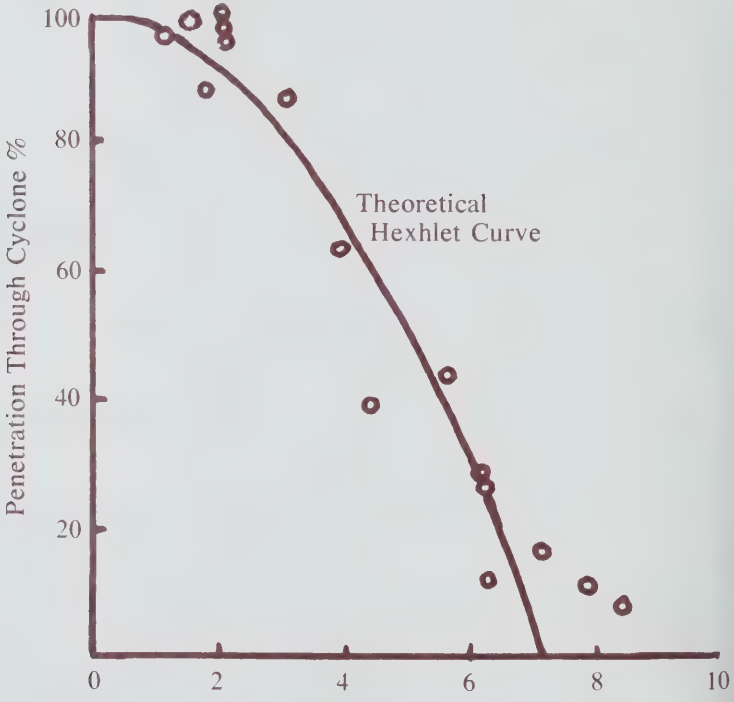
Based on the aforementioned arguments, it can be concluded that the ACGIH specified size-selective device, such as the nylon cyclone, should give mass concentrations closer to that predicted by the pulmonary deposition curve. Conversely, for a respirable sampler conforming to the BMRC criterion, such as the Casella cyclone sampler, the respirable mass will not be that close to the pulmonary deposition curve.

Size-selective Characteristics of a BMRC Metal Cyclone

The size-selection curve for the Casella cyclone, designed by Higgins & Dewell, is shown in Figure 2.

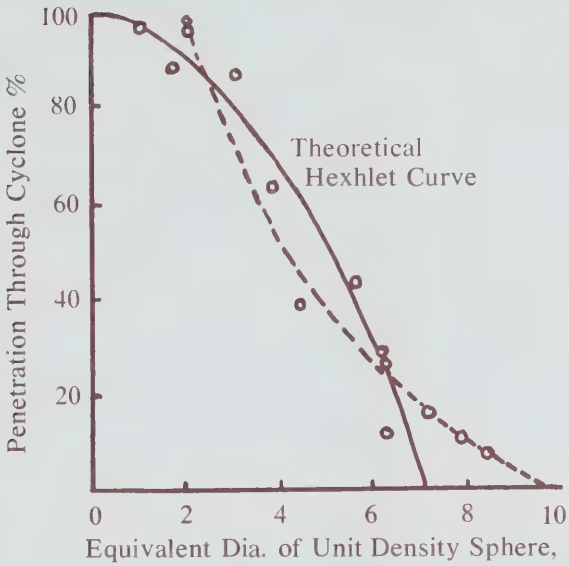
Figure 2

Selection Characteristics of BCIRA Personal Cyclone



The proponents of the Casella cyclone maintain a firm stand and assume that it conforms to the theoretical Hexhlet curve, which is the reference instrument for the BMRC curve, as shown by a solid line in Figure 2. The BMRC curve shows a sharp cut-off curve at 7μ, which is unrealistic for a cyclone penetration curve. In addition, for the Casella cyclone, the size-selection data points can also be joined to yield a curve that tends to show a 10μ cut-off, as illustrated by the dotted line in the redrawn Casella cyclone curve shown in Figure 3.

Figure 3 Redrawn Size Selection Curve of the BCIRA Personal Cyclone



It is pertinent to note in Figure 3, that the Casella cyclone's size-selection curve does not follow entirely the BMRC Hexhlet curve. For particles greater than 6μ, the cyclone curve tails off like the ACGIH curve, which may have some implications on respirable mass collected. As quartz is a very hard mineral, it resists being broken into smaller particles. Thus, the proportion of quartz in the 7 to 10μ size range is likely to be greater than in the 2 to 3μ range. If the redrawn Casella cyclone curve is acceptable, it could lead to higher quartz concentration than expected from the BMRC curve that cuts off at 7μ,

Size-Selective Characteristics of the Nylon Cyclone

Lippman and Harris[3] did pioneer work on the original HASL 10 mm nylon cyclone. The collection characteristics of the nylon cyclone were studied at various sampling rates. They concluded that, at a flow rate of about 2.8-Lpm or less, the nylon cyclone satisfies the ACGIH criterion, although for the 10 mm Dor-Oliver Nylon Cyclone, this flow rate has been revised recently.[11] Unlike Casella data points, it is observed that most of the calibration data points of the 10 mm nylon cyclone approximate the ACGIH curve. In other words, the 10 mm nylon

cyclone approximates more closely the ACGIH criterion than does the Casella cyclone to the BMRC curve, as was demonstrated earlier.

To put forward some additional evidential arguments in support of the 10 mm nylon cyclone, it seems quite appropriate here to review briefly the pertinent work reported and evaluated in terms of its applicability to lab and field conditions.

A critical discussion of major investigative work conducted on the 10 mm nylon cyclone has been presented by Tomb and Treaftis.[11] Among the many investigations, Ayer's work in the Vermont granite industry is of great significance to us.

Comparative Respirable Mass Sampling in the Vermont Granite Industry

Ayer and co-workers,[12] in their study of the Vermont Granite monument industry, used the 10 mm nylon cyclone along with other size-selective samplers. In order to relate the respirable mass measurements to conditions known to produce silicosis, the concerned US regulatory agencies in the early 1970s suggested that conditions of the 1920s be recreated in a non-operating granite shed. A small granite shed in Barre, Vermont, was operated for one week without any ventilation, and granite cutters were protected by respirators. Respirable dust concentrations of up to 49 mg/m^3 and free-silica concentrations of up to 4.4 mg/m^3 were observed. The purpose of this study was also to compare the respirable mass by using different size-selective samplers. Mass concentrations determined in this study by the fixed station comparative samplers are summarized in the following Table.

Average Respirable Dust Concentrations Using Various Samplers[12]

Horizontal Elutriator Samplers	**mg/m^3**
Isleworth (MRE) Sampler (2.5-Lpm)	10.7
10-Lpm (NIOSH) Elutriator	11.6
Hexhlet (50-Lpm)	14.4
Cyclone Samplers	
½ inch Steel Cyclone at 10-Lpm	10.9
10 mm Nylon Cyclone at 1.7-Lpm	10.7

From this Table, it is obvious that for all practical purposes, the 10-Lpm elutriator, the Isleworth Sampler, the HASL ½" steel cyclone and the 10 mm nylon cyclone, at the specified flow rates, are

equivalent in average performance. This study thus supports the justification of the Ministry of Labour in choosing the 10 mm nylon cyclone for respirable dust sampling purposes in Ontario.

Recommendation of the 10 mm Nylon Cyclone for Respirable Mass Sampling by the AIHA Aerosol Technology Committee

In 1970, the Aerosol Technology Committee of AIHA published a Guide for Respirable Mass Sampling.[13] Of the five size-selective sampling devices suggested, the 10 mm nylon cyclone was the only lightweight presampler that conformed to the ACGIH size-selection sampling criterion. For this cyclone, flow rates of 2.0, 1.7 and 1.4-Lpm have been reported. The Aerosol Committee recommended that a flow rate of 1.7-Lpm be tentatively adopted to approximate the ACGIH respirable dust definition. Also, experience with this sampler indicates that data obtained at a flow rate of 1.7-Lpm can be converted to 'equivalent concentrations' for either the higher or lower flow rate, if necessary.

Calibration of the 10 mm Nylon Cyclone

The 10 mm nylon cyclone has been calibrated by Lippman[14] Sutton,[15] Knuth,[16] Tomb,[17] Ettinger,[18] Knight,[19] and Caplan.[20] The main objective of these calibrations was to determine an operational flow rate so that the collection characteristics of the cyclone would closely match the ACGIH size-selection criterion. A review of all the calibration techniques suggests that the 1.7-Lpm flow rate recommended in the AIHA Guide for Respirable Mass Sampling is a reasonable choice for the recommended sampling rate.

Conclusion

It is difficult to find an ideal sampling technique; each technique has its limitations. Neither of the two respirable mass sampling criteria could ever be considered perfect. However, an inter-comparison of the two size-selection curves with the pulmonary deposition data, indicates that the ACGIH specified size-selective device, such as the nylon cyclone, gives respirable mass concentrations closer to the predicted value of the pulmonary deposition curve.

In Ontario, for industrial hygiene monitoring and exposure control purposes, the Ministry of Labour has adopted the ACGIH recommended Threshold Limit Values (TLVs). It is logical, therefore, to use a size-selector that conforms to ACGIH specifications. The size-selective characteristics of a 10 mm nylon

cyclone approximate more closely the ACGIH criterion than does the Casella cyclone to the BMRC curve.

The 'Comparative Respirable Mass Sampling Study', carried out in the Vermont granite industry, indicated that for all practical purposes, the 10-Lpm elutriator, the Isleworth Sampler, the HASL ½ steel cyclone at 10-Lpm, and the 10 mm nylon cyclone at 1.7-Lpm were equivalent in average performance. This study presents the strongest argument in favour of the 10 mm nylon cyclone for respirable mass sampling applications, because of the aforementioned reasons.

In Ontario, where both ACGIH and BMRC criteria have been used in the past, attempts should be made to resolve the existing inconsistencies so as to achieve uniformity in size-selection data. Furthermore, if Ontario goes against adopting the ACGIH criterion, we may have to adopt the two criteria. This will keep the confusion, and uniformity will never be achieved.

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History of the Occupational Health Laboratory Ontario Ministry of Labour

Summary

The work done by the laboratory from its inception in 1921 to the present is reviewed.

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Introduction

The protection of workers against health hazards associated with their workplace is not a new concern in Ontario. The Division of Industrial Hygiene was founded in 1921 as part of the Ontario Board of Health,[1] and the associated laboratory was established shortly afterwards. The history of the laboratory, stretching over half a century, accordingly reflects the increasing awareness of health hazards in industry, the recognition of new hazards and the improvement of methods for their evaluation.

The laboratory was housed in the Whitney Block in Queen's Park from 1921-1951 and then moved to temporary quarters in an old building at 360 Christie Street. It continued to operate there until 1981 when it was moved to a modern new laboratory building on Resources Road in Weston.

The laboratory was known for many years after its founding as the Industrial Hygiene Laboratory. There were many reorganizations and name changes, but it has been known as the Occupational Health Laboratory since 1969. The laboratory was part of the Ministry of Health until 1976 when it was transferred to the Ministry of Labour. The Geohygiene Laboratory, which was largely concerned with dust exposures in mining, and which was part of the Ministry of Natural Resources, was amalgamated with the Occupational Health Laboratory.

In the early days, the available analytical methods lacked sensitivity and necessitated the sampling of large volumes of air with bulky air sampling equipment that was difficult to place in the worker's breathing zone.

Until 1975, the collection of air samples, as well as the laboratory work mentioned above, was done by laboratory personnel. Numerous special investigations not directly related to our main role, such as fumigation inspection and the detection of second-hand material in stuffed articles, were also undertaken.

The laboratory assessment of health hazards from industrial exposures to toxic materials is performed

in three ways. First, bulk materials of unknown or uncertain composition are analysed for the presence of toxic materials. Secondly, biological samples, usually urine or blood, collected from workers can be analysed for the toxic substances themselves or their metabolites; in some cases, tests are made to ascertain their physiological effects. Finally, samples of air are collected from industrial sites, and analyses are later performed in the laboratory to ascertain the concentrations of toxic substances in the air inhaled by the workers.

Assessment of Lead Exposures

The early interest of the Division of Industrial Hygiene in lead poisoning is evidenced by its publication of a book on the subject in 1923.[2] The book included a survey of medical literature and a compilation, written by W.E. Green, the division chemist, on laboratory and clinical tests for lead.

The determination of lead in urine must have been an unpleasant chore in those days since the methods described involved the evaporation of several litres of urine while it was being constantly watched to avoid its boiling over. This malodorous task was followed by precipitation of the lead with hydrogen sulphide. More regularly, the counting of blood smears for stippled erythrocytes was relied upon for routine monitoring of workers exposed to lead. A detailed description of the latter technique was published[3] and it was stated that the test was run almost daily from 1924.

The purchase of a Coleman spectrophotometer in 1941 and the introduction of the dithizone colorimetric method enabled the analysis for lead in urine to be run more frequently as a supplement to the counting of stippled erythrocytes. In 1967, the dithizone method was replaced by flame atomic absorption with direct aspiration of the urine, and this was adopted as a screening test to detect excessive absorption of lead in workers. At present, about 15,000 urine samples per year are analysed by this method. When the urinary lead tests indicate excessive exposure, blood lead analyses are used as a supplement and, in certain groups of workers who have a potentially heavy exposure, lead in blood analyses are now run routinely in place of urinary lead tests.

After the introduction of atomic absorption, a method was developed in this laboratory involving oxidation of blood with nitric acid and hydrogen perioxide, subsequent evaporation and preparation

of a solution of the residue in one per cent nitric acid and measurement of the lead content by flame atomic absorption with background correction. This laborious method has now been replaced by the Delves cup procedure in which microlitre amounts of blood are dried in nickel cups and introduced directly into the flame. Alternative tests on biological samples involving the interference of lead with porphyrin synthesis in the organism, are now being investigated.

The method of air sampling for lead, described in the book published by the Division of Industrial Hygiene in 1923,[2] was to draw air through cotton wool by a suitable pump. The lead was dissolved out of the cotton wool with nitric acid and the amount of lead estimated visually after precipitation with hydrogen sulphide. The air samples were later collected in large impingers containing one per cent nitric acid and the amount of lead estimated by dithizone. The introduction of the more sensitive atomic absorption method made possible the employment of smaller impingers and air sampling pumps. Recently, filters have replaced impingers. These allow the air sampling equipment to be pinned to the clothing of the workers.

At present, employees of about 150 plants in Ontario are being regularly monitored for lead. The work in which these people are employed include the manufacture of lead storage batteries, recovery of lead from scrap, paint formulation, paint pigment manufacture, autobody grinding and the production of vitreous enamels. As well as regular monitoring in industry, various special investigations have been undertaken. These include determining the amount of lead in coloured chalks used in schools (1937), the amount of lead in the blood of people living near lead smelters (1972-73), the amount of lead in paint chips and dusts from old dwellings (1973-75) and the concentration of lead fume in the air of brass foundries (1978-79). In 1943, laboratory tests were performed to determine the effectiveness of regulations requiring the labelling of containers in which lead was present in the contents.

Assessment of Mercury Exposure

The first instrument designed for measuring the concentration of mercury in air was the Norelander mercury detector. It was used for the first time in 1941. This instrument utilized a light bulb to generate convection currents in the air. The air flowed over paper impregnated with selenium sulphide,

which turned black in the presence of mercury. In 1944, a method was adopted involving collection of air samples in a large impinger containing acidified potassium permanganate, and analysis by a dithizone colorimetric procedure. In 1970, the analytical technique was changed to the more sensitive cold vapour atomic absorption method. This enabled the air samples to be collected in small impingers. The use of solid adsorbents to enable sampling to be done with the sampler pinned to the workers' clothing is under investigation.

Biological monitoring has always been carried out by analysing for mercury in the urine of exposed workers. This was started in 1944 using acidified potassium permanganate to oxidize organic matter, and analysing for mercury by a colorimetric dithizone method. A detailed investigation of the method performed in this laboratory[4] showed that, in old urine specimens, bacterial contamination could increase the volatility of mercury unless care was taken to avoid heating prior to adding the oxidant. In 1970, the less laborious Rathje method was adopted in which the oxidation is performed with nitric acid at room temperature, and the analysis for mercury is by cold vapour atomic absorption.

In the early days of this laboratory, there were few mercury exposures in the province, and these were largely confined to the electric industry, seed treating and fur storage. After the Second World War, the number of workers exposed to mercury in Ontario increased greatly due to the widespread use of mercury cells in the electrolytic process for making chlorine and caustic soda from salt. In recent years, these mercury cells have been largely replaced by cells that do not use mercury. As a consequence, the number of workers exposed to mercury in Ontario has now decreased.

Assessment of Arsenic Exposure

Arsenic analyses have been carried out since the earliest days of this laboratory. For many years, various modifications of the Gutzeit method were employed in which arsine was generated and passed through filter paper impregnated with mercuric chloride or mercuric bromide. The amount of arsenic was estimated visually from the colour. This was replaced, in 1965, by a method in which the arsine was reacted with silver diethyldithiocarbamate and the colour measured instrumentally. Urine, hair and finger nail samples are analysed for arsenic after

prior oxidation of the organic matter. Air samples were, at first, collected in impingers but are now collected on filters. An alternative method employing atomic absorption is at present under investigation.

The main exposures in Ontario have been associated with the treatment of arsenical silver and gold ores, and the number of workers exposed has varied with the fluctuating fortunes of these industries. Before the advent of provincial laboratories devoted to water analysis, this laboratory also analysed water and sediment samples for arsenic. It was involved in a special investigation of an arsine exposure in a gold mill where the filters used in treating arsenical gold ore were cleaned by immersion in dilute acid.[5]

Assessment of Nickel Exposure

The earliest annual reports indicate that nickel rash and the contamination of food from nickel dishes were one of the first interests of the Division of Industrial Hygiene. An attempt was made, in co-operation with the University of Toronto, to find a correlation between nickel rash and the uric acid concentration in blood.[6] In the 1924 annual report, it was stated that one ppm of nickel in organic matter could be measured, but the methodology was not described. For many years, nickel was measured by a colorimetric process using dimethylglyoxime; this was later replaced by atomic absorption.

Measurements of nickel in air and biological samples have been undertaken in connection with workers' exposure in nickel smelting and refining, welding of stainless steel and the use of nickel carbonyl. In 1949, a special investigation was conducted, including autopsy specimens, of three deaths from nickel carbonyl poisoning.

Assessment of Exposure to Other Metals

Other metals for which analyses have also been performed in this laboratory include aluminum, beryllium, cadmium, cobalt, chromium, copper, iron, manganese, thallium, antimony, vanadium and zinc. The analyses were performed on biological samples (usually urine), bulk samples or solutions from air sampling, formerly by colorimetric methods and now by atomic absorption. The air samples were, at first, collected in large impingers, then in small impingers, and are mostly now collected on filters.

Frequently, the laboratory is called upon to analyse for unspecified toxic metals in samples where

the composition is unknown. From 1959 until recently, such samples were first analysed by carbon rod emission spectroscopy to give a qualitative or semi-quantitative estimate of the toxic metals present. If any were found, these were determined quantitatively by colorimetry or atomic absorption. This procedure has now been superseded by the use of inductively coupled argon plasma emission spectroscopy. By this means, approximately 30 elements can be determined simultaneously and quantitatively in concentrations encompassing several orders of magnitude.

The determination of some toxic metals in biological samples frequently requires greater sensitivity than can be achieved by flame atomic absorption. Electrolytic methods and furnace atomic absorption are being investigated for use in such determinations.

The use of these metals encompasses a wide variety of industrial exposures. Special investigations were conducted in the grinding of antimony trisulphide[7], deaths from exposure to freshly formed cadmium oxide fumes[8] and the use, in 1946, of plastic floats to reduce chromium exposures in chrome plating. An investigation into the analysis of cadmium in urine by atomic absorption, using a non-absorbing line from a lead lamp to correct for salt scatter, was carried out in this laboratory.[9] This method was used until the advent of simultaneous background correction.

Measurement of Dust Concentration in Air

One method of determining dust concentrations in air is to draw a measured volume of air through a pre-weighted filter and to weigh the filter afterwards. As a method of establishing the presence of a health hazard, it has the serious disadvantage of being inconclusive. Most of the weight of the total airborne dust collected consists of large particles that do not enter the respiratory tract and, hence, may not cause industrial-related diseases. This method is still used to determine the concentration of some dusts, such as wood dust, in air. The measurement of total airborne dust was used in 1970 for a survey of cotton dust exposures; such measurements are now done by a special device that collects the respirable fraction of the dust.

In 1932, the United States Public Health Service adopted a method of assessing dust exposures by which the air was drawn through water in an im-

pinger, an aliquot of the suspension was transferred to a counting cell and the number of particles counted microscopically. This laboratory made a detailed study of the method.[10] The results obtained were subject to many variables, such as the standing time of the sample, the illumination of the counting cell and the experience and visual acuity of the operator. Care was taken to standardize the counting procedure as far as possible, and this method remained the usual method for dust assessment until recent years. Air samples for the concentration of respirable dust are now taken by a small pump and cyclone separator, which are attached to the workers' clothing. The cyclone separates the coarse particles of dust from the respirable particles, which are collected for example on a pre-weighed silver membrane filter for subsequent weighing and analysis for quartz by X-ray diffraction. Because of the extremely small weights involved, special care must be taken to avoid contamination of the sample and errors due to changes in humidity in the weighing room and vibration of the balance.

Over the years, many surveys of conditions were made in industries where there were exposures to dusts containing free silica. Dust counts and analyses of the total airborne dusts for free silica were carried out by the methods described in the next section. Examples of such industries are foundries, ceramic plants and granite cutting. Nelson *et al* paid special attention to the manufacture of silica flour and its uses in ceramic plants and in the production of abrasive cleaners and concrete blocks etc.[11] This paper also included work correlating dust counts with respirable mass measurements.

In the early years, silica flour was largely used as partine in foundries. To reduce the sillicosis hazard, silica flour was replaced by calcium carbonate and the changeover was largely completed by 1943. During this period, the laboratory was active in the analyses of partines. In the 1950s 'natural' sands (naturally occurring mixtures of sand and clay) were largely replaced by 'synthetic' sands (prepared mixtures of coarse silica sand and bentonite) in iron foundries. A survey conducted by this laboratory showed that, under comparable conditions, this changeover resulted in lower dust counts and in a reduction in the free silica content of the total airborne dusts.

Special surveys were made of dust conditions in a tunnelling operation at Niagara Falls, Ontario in 1953, the silicon carbide industry in 1953 and 1954, bean elevators in 1964, brick plants in 1970 and 1971[12] and mining operations at Elliot Lake in 1974.[13]

Analysis for Free Silica

In assessing the silicosis risk in mines, quarries and industry, a knowledge of the free silica content of the raw materials and dusts is required. This free crystalline silica usually occurs in the form of quartz. When the amount of dust in the air was measured by dust counting, the standards for permissible exposures required an analysis of the total airborne dust for free silica.

For many years an approximation of the free silica content of materials and dusts was obtained by the classical gravimetric methods used for rock analysis. The amount of total silica (free and combined) was measured, the amount of combined silica estimated from the alumina content and the amount of free silica estimated by the difference. A detailed study of the direct gravimetric measurement of the free silica content by the phosphoric acid method was made in this laboratory in 1953 and 1954.[14] This method was then adopted and is still being used, in conjunction with X-ray diffraction, for the analysis of rocks, industrial raw materials and dusts.

When the method of assessing dust concentrations in air by separating and weighing the respirable fraction of the dust was introduced, a method of estimating the free silica content of the minute weight of respirable dust collected in each sample was required. The gravimetric method was obviously unsuitable. The measurements of the amounts of quartz on the silver membrane filters are made by a computerized X-ray diffraction instrument. This instrument features automatic feed and computerized averaging and printing. An early use of X-ray diffraction was a qualitative study, sponsored by this laboratory, of the minerals present in silicotic lungs.[15]

Assessment of Asbestos and Talc Exposure

Prior to 1969, air sampling for asbestos exposure was done by the usual impinger and counting method. The method was unsatisfactory, especially in mixed exposures, since fibres of chrysotile asbestos curl up in the water in the impinger and are indistinguishable under the microscope from other

dusts present. In 1969, the now widely used method of fibre counting, based on collection on a filter and counting by phase contrast microscopy, was started. This laboratory participated in a statistical study of the errors involved in the counting.[16] While the method distinguishes asbestos from non-fibrous dusts, it does not distinguish asbestos from other fibrous materials, such as cellulose.

Commercial talc has a widely varying composition and can contain fibrous material, usually in the form of tremolite or talc fibres. The usual method of assessing total dust exposure is used in air sampling for non-fibrous talc and the asbestos method is used for fibrous talc.

For many years, infrared spectroscopy was used in this laboratory for the detection of asbestos in insulating materials, etc. and to study the composition of talc samples. Infrared spectroscopy has now been superseded by X-ray diffraction and examination under a polarizing microscope.

The health hazard associated with asbestos is related, in a complex manner, to the amount, size, shape and chemical composition of the fibres. At present, this poorly understood relationship is being studied by electron microscopy.

Exposures to asbestos and talc in Ontario are very numerous in industry, construction and mining. Adequate assessment and control of these exposures will present a continuing challenge for years to come.

Assessment of Exposures to Other Inorganic Substances

Hydrogen sulphide in air was formerly measured by bubbling the air through a solution of a cadmium salt and visually estimating the amount of cadmium sulphide formed. This measurement is now done directly by colour change tubes. In the late 1930s, a special survey of exposures to hydrogen sulphide and carbon disulphide (also measured colorimetrically) in the rayon industry was conducted.

Air samples for flouride or hydrogen flouride are collected in an alkaline solution in impingers. The first analytical method employed was titrimetric; afterwards a colorimetric method with alizarin complexone was used. The analysis is done today by a specific ion electrode. The analytical methods for flouride in urine followed the same sequence. In 1967 and 1968, the laboratory participated in a special survey of the Port Maitland area, which included the analysis of community water and urine

samples. Most industrial exposures to flouride occur in the phosphate fertilizer industry.

Carbon monoxide in air was formerly measured by an instrument that oxidized the carbon monoxide to carbon dioxide by drawing the air over Hopcalite. The heat of combustion activated a thermocouple, which was connected to a meter calibrated to read the amount of carbon monoxide in the air directly. The measurement is now done by colour change tubes in numerous types of exposures. In 1946 and 1947, a special survey was carried out of carbon monoxide in garages. Measurements of carboxyhemoglobin in blood were formerly done in this laboratory, but have been discontinued for many years. They will be restarted in the future with the acquisition of a new sophisticated spectrometer.

In the 1950s, diesel equipment began to be used extensively in Ontario mines. Samples of the exhaust gases from various engines were submitted to the laboratory and analysed for carbon monoxide (colour change tubes), total oxides of nitrogen (colorimetric, i.e., a coloured solution was produced) and formaldehyde (colorimetric). In 1958, an air sampling survey was made in mines where diesel equipment was being used, and tests were run for nitrogen dioxide (colorimetric) and carbon monoxide (colour change tubes).[17] The same types of samples were later taken in mines when blasting with mixtures of ammonium nitrate and fuel oil was introduced.

Assessment of Benzene Exposure

Benzene exposures were one of the first concerns of the Division of Industrial Hygiene. In the early reports, the substance was always referred to as 'benzol', a technical grade of impure benzene. It appears that benzene was much more widely used in those days than it is today in such things as paints and adhesives.

An example of an early investigation occurred in 1923 in a case of acute benzene poisoning in a tank that was being painted with a coal tar paint diluted with benzene. It was stated in the annual report that 'by proper precautions, and the testing of the concentration of the fumes by rabbits, which are sensitive to the fumes, the work was finished without trouble.'

Air sampling methods for benzene were investigated as early as 1925, but the methodology is not known. In the 1940s, air sampling was done by leading the air over glass beads soaked in nitric and

sulphuric acids. Water was allowed to flow slowly from a five-gallon bottle to draw the air through the sampler. The analysis was done colorimetrically. Direct reading colour change tubes were first employed in 1953. From 1960 to 1976, the method used was adsorption on silica gel, desorption with carbon disulphide and analysis by infrared spectroscopy. Charcoal adsorption tubes and analysis by gas-liquid chromatography are now used. This permits personal sampling, whereas the older methods were suitable only for taking air samples at fixed locations in a plant.

In biological monitoring of benzene exposures, the main reliance was placed on routine hematology tests. An investigation of the measurement of organic and inorganic sulphates in urine was conducted in this laboratory,[20] but it was concluded that this test was not reliable as an indication of benzene exposure. At present, analyses of phenol in the urine of exposed persons are being carried out, formerly by a colorimetric method and now by gas-liquid chromatography.

The determination of benzene in solvent mixtures, particularly when mixed with petroleum fractions, presented many difficulties in the early days. Reliance was placed on fractional distillation followed by nitration and colorimetric tests. No really satisfactory method for the analysis was available until an infrared spectrophotometer was purchased in 1959. This is now supplemented by gas-liquid chromatography when greater sensitivity is desired.

Over the years, benzene has been largely replaced by other solvents in consumer products. The main exposures today are in petroleum refining, the processing of coal tar and chemical manufacture.

Assessment of Other Solvent Exposure

The number of new solvents introduced into industrial use since the founding of this laboratory has created many new analytical problems, especially as these solvents are often mixed for use in paints, adhesives, cleaners, etc., and as the user usually has no idea of the composition of these products. Fire hazards were assessed by the use of flash points in the laboratory and by combustible gas and vapour indicators in the field. However, much more sensitive and specific methods were needed for the assessment of health hazards.

Before 1959, fractional distillation and the use of physical and chemical tests were relied upon for solvent analyses in industrial materials, but these

tests were unsatisfactory and, often, definite answers could not be obtained. The situation was much improved in 1959 with the purchase of an infrared spectrophotometer. This enables, in most instances, identification and quantification of the major constituents of solvent mixtures to be made. In recent years, the more versatile and sensitive method of gas liquid chromatography has also been employed.

Air sampling for solvent vapours was formerly in a very unsatisfactory state. Specific methods were available in a few cases; for instance, a colorimetric method of air sampling for methanol was developed in this laboratory.[21] In 1938, a combustion aparatus was purchased for the measurement of chlorinated hydrocarbons in air. The combustion of the solvent vapours in a heated tube produced chlorine and hydrogen chloride, which were collected in an absorbing solution. The amount of chloride ion was measured by titration. It could, of course, be used only when one known chlorinated hydrocarbon was present in the air. Colour change tubes for solvent vapours began to appear in the 1950s. After the purchase of the infrared spectrophotometer in 1959, a method involving adsorption on silica gel, desorption in carbon disulphide and measurement of the intensity of characteristic infrared bands was investigated in this laboratory. It proved suitable for the common aromatic and chlorinated hydrocarbons but could not be applied to other solvents. A general method, now used for all solvent vapour air samples, involves adsorption on charcoal and analysis by gas liquid chromatography. The identification is confirmed by an instrument that combines gas chromatography and mass spectroscopy.

Monitoring of blood and urine samples for solvents and their metabolites has, up to now, not been extensively used in this laboratory, but will probably be used more in the future, employing chromatographic techniques. A non-specific colorimetric test for trichloroacetic acid in urine to monitor trichloroethylene exposures was employed many years ago.

Assessment of Exposures to Organophosphorus Insecticides

Assessment of the exposures of workers mixing and packaging organophosphorus insecticides cannot be satisfactorily done by air sampling since the materials handled vary widely from day to day. Consequently, a measurement of enzyme activity, namely, the reduction of the cholinesterase activity of the blood, is relied upon for routine monitoring. This

was formerly done by a titrimetric method, but the more commonly used Michel method has been employed here for about 20 years.

Colorimetric analyses for parathion were formerly used for air sampling, clothing and autopsy specimens, but now chromatographic methods are used for analyses of air samples containing any of several insecticides.

Other Organic Materials

During the Second World War, many analyses for TNT and tetryl were run by colorimetric methods on air samples, urine specimens and workmen's clothing. In connection with this program, many blood specimens were also examined for hemoglobin and methemoglobin. A method of air sampling and the measurement of nitroglycerine and ethylene glycol dinitrate in the presence of each other, based on selective hydrolysis, was developed in this laboratory in 1949. This method was adopted by industry for routine monitoring.

Numerous plants have been visited in the last 20 years, and air samples taken where isocyanates were used in the manufacture of polyurethanes. The colorimetric test used is non-specific in that a colour is also given by aromatic primary amines. More specific chromatographic means of analysis are now used when these amines are also present. Infrared spectroscopy has been employed for many years for the identification of the types of plastics in commercial products. The study of the products formed when plastics are decomposed by heat had been accomplished by the pyrolysis of the plastics under controlled conditions; the products are identified by chromatography. In general, charcoal tube or filter samples of the chemicals used are taken in the field for subsequent chromatographic analysis.

Air samples for petroleum oil mists have been collected on filters and analysed for total hydrocarbons by infrared spectroscopy since 1964. The method was developed in this laboratory[22] to replace the previously used gravimetric method, which was not applicable in the presence of metal dust. Infrared spectroscopy has been used for many years for the qualitative analysis of aqueous cutting fluids, and other procedures are being investigated for nitrosamine analysis when nitrites and amines are present. Both petroleum-based and aqueous cutting fluids are widely used in machining operations.

Infrared spectroscopy has been used to examine such diverse substances as detergents, amine catalysts for epoxy resins, fuel oils and even kidney stone composition.

Chromatography has also been used for PCBs, coal works and coke oven emissions.

Fumigation

Detailed regulations regarding the use of cyanogen and cyanide compounds in fumigation became effective in 1933 and were enforced by the Division of Industrial Hygiene. For the next decade, the chief chemist of the laboratory spent much of his time conducting examinations and inspections and enforcing the regulations. After the Second World War, these activities diminished due to the introduction of synthetic organic pesticides. This inspection function was later transferred to a special section of the division.

In 1944, laboratory personnel conducted the first experimental spraying with DDT in the province at the Whitby Mental Hospital and the Langstaff Jail Farm.

Upholstered and Stuffed Articles

The question of the possible effects on health of the use of second-hand material in mattress manufacture was first raised in 1925, but it was not until 1938 that regulations were passed, under the *Public Health Act* prohibiting such use. The enforcement was made part of the activities of the Division of Industrial Hygiene, and the laboratory was given the task of devising suitable testing procedures.

Numerous possible tests were investigated[23,24] and a method that depended upon the visual inspection of the difference in fluorescence between new and used material when they were examined under ultra-violet light was finally adopted. These tests were carried out in this laboratory until 1969 when they were transferred, along with the inspections, to the Department of Financial and Consumer Affairs.

Conclusion

The Occupational Health Laboratory dates from the days when health hazards associated with industry and mining were but dimly understood, and analytical methods were restricted to visual, gravimetric and titrimetric procedures. During the more than half a century that has elapsed since its founding, there has been an increasing awareness of old and new health hazards, and modern methods of sam-

pling and instrumental trace analysis have become available. Due to the widely varied nature of industry and mining in Ontario, most of the problems in occupational health have been encountered in this province, and the history of the laboratory reflects these developments. The laboratory has, at times, been given tasks outside the field of occupational health.

The years have also seen a lowering of permissible exposures to many substances in an effort to reduce human health hazards. The development of even more sensitive analytical methods of determining toxic substances will be required. Biological methods of analyses, such as animal testing and mutagenicity testing, will probably play an increased role.

Acknowledgements

The material for this history has been drawn from several sources. While the laboratory is mentioned in departmental annual reports, the accounts are sketchy and incomplete. These have been supplemented by laboratory records, published literature, recollections of Mr. J.H. Johnston, who was employed as a chemist from 1940 to 1953, and the memories of the author. The assistance of Mrs. Jean Collins-Williams of the Ontario Ministry of Labour Library is gratefully acknowledged.

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Book Review

Occupational Hygiene — An Introduction Text. Edited by H.A. Waldron and J.M. Harrington. 423 pages. Blackwell Scientific Publications

As the title describes, this book is written for the beginner in the field of occupational hygiene. The intent is very well spelled out in the preface: 'The purpose of this book is to provide a clear and concise account of the principles of occupational hygiene, as such, it is suitable as a primer....'

The book is written in a simple and readable style. There are altogether 16 chapters written by different authors dealing with the various aspects of occupational hygiene. The approach to the subjects is systematic, starting with the physics of gases and aerosols, followed by sampling, health effects, ventilation, noise and vibration, light, heat, radiation, respirators, environmental control, statistics and epidemiology. After each chapter, the authors have suggested other textbooks for further reading which, in my opinion, helps to keep the book concise and precise.

This reviewer found Chapter 14 on 'Environmental Control — Current Concepts' particularly interesting. In this chapter, Dr. Waldron discusses standards, risks and hazards, does-response curves, multiple exposures and international comparison of hygiene standards, but he discusses them rather briefly. These complex subjects either should not have been touched on or they should have been explained by giving practical examples. For instance, calculations of TLVs for mixtures can be better explained by giving a few numerical examples. However, these are minor points in a good and useful book. Therefore, whether employed for teaching or learning, this book will be an invaluable addition to the library of occupational hygienists.

G.S. Rajhans

News and Notes

In April and November of each year, the Queen's University Occupational Health and Safety Resource Centre offers a training course in Industrial Audiometry and Hearing Conservation. This course has been designed to meet the Ministry of Labour's recommendations for appropriate training of audiometric technicians in industry. Students are recruited from among occupational health nurses and safety technicians, but those who supervise occupational health and safety programs would also benefit from the course. On successful completion of the course, students should have a knowledge of the concepts of hearing conservation, an understanding of the physical measurement of sound and the practical ability to undertake competent audiometry. They will also be aware of the ethical and legal considerations surrounding audiometry and be familiar with record keeping techniques. For further information, contact the Occupational Health & Safety Resource Centre, Queen's University, 25 Union Street, Kingston, Ontario. K7L 2N6.

American Occupational Health Conference

For the first time, the American Association of Occupational Health Nurses and the American Occupational Medical Association are holding their annual joint conference outside the United States.

Over four thousand (4,000) professionals are expected to attend this year's two-day conference to be held in Toronto, Ontario, on April 28 and 29, 1982. It is the largest international conference of its kind. The objective is to support the continuing education of registered nurses and physicians in the speciality of occupational health. This year's emphasis will on the Canadian perspective with many topics that go beyond the limitations of national and regional boundaries.

There are professional development seminars for association members on the days preceding and after the conference dates. Over seventy (70) speakers specializing in occupational health and related subjects will cover a full range of topics

associated with the promotion and maintenance of physical, social and mental well-being of men and women who work.

Second International Symposium

Epidemiology in Occupational Health

Purpose of the Symposium
The first symposium of the Scientific Committee on Epidemiology in Occupational Health took place in Helsinki in June, 1981. Following this successful and well attended meeting, the committee decided that a symposium should be held each year, except for the year of Triennial Conference. The purpose of the 1982 symposium is to bring together the growing number of occupational epidemiologists to discuss methodology, findings and applications of their work.

Attendance
The symposium is mainly for active research workers in the field of occupational health.

Time and Place
The symposium will be held, August 23-25, 1982, at the McIntyre Medical Sciences Building, McGill University, Montreal.

Preliminary Scientific Program
Papers are invited on any application of epidemiology in occupational health. Papers dealing with methodological questions, occupational epidemiology in developing countries and the application of epidemiology to the administration of national occupational health services will be specially welcomed.

Enquiries and Pre-registration
If you are interested in attending the symposium, please write for application form to:

Epidemiology Secretariat
772 Sherbrooke West, Montreal, Quebec, Canada
H3A 1G1

Telephone: (514) 392-6744 Telex: 05-268510

International Symposium on the Protection of Workers against Vibration

September 21-24, 1982

This symposium, organized in Niš (Yugoslavia) by the Institute 'Edvard Kardelj' of Occupational Safety and Health Documentation in co-operation with the International Labour Office, will discuss the following items:

1. Health effects and exposure limits (health effects of hand transmitted and whole body vibration;

relationship between pathological conditions and the frequency and other characteristics of vibration; medical examinations, diagnosis and tests; health based criteria and exposure limits).

2. Physical quantities and measurements (measurement units and application of the International System of Units; measuring equipment methods used for the measuring of vibration emitted by equipment, and for the evaluation of occupational exposure; standardization of measuring apparatus and methods; relationship between methods of measurements and exposure limits).
3. Preventive and protective measures (equipment design, prevention at the source, and of transmission of vibration; protective equipment, organization of work, preventive programs including employers' and workers' co-operation, legislation and standards).
4. Vibration hazards in various branches of economic activity (epidemiological studies, preventive and protective measures; agriculture, forestry, industry, mines, transport, building and public works, etc.).

Working languages
English, French, Spanish, German, Russian and Serbo-Croat.

Further information may be obtained from:
Occupational Safety and Health Branch,
International Labour Office,
CH-1211 GENEVA 22 (Switzerland)

Telex: 22.271 BIT CH

Telephone: (022) 99 67 15

Mrs. Dragica Kocić, Secretary of the National organising Committee,
Institute of Occupational Safety and Health Documentation 'Edvard Kardelj',
Višegradska 33, pp 141,
18000 Niš (Yugoslavia)

Telex: 16284 YU INSDOK

Telephone: (38-18) 338-974

Coming Events

April 28-29, 1982	American Occupational Health Conference, Toronto, Ontario
May 17-19, 1982	Inter-Noise 82, the eleventh International Conference on Noise Control Engineering, the Jack Tar Hotel, San Francisco. Conference Secretariat: Noise Control Foundation, PO Box 3649, Arlington Branch, Poughkeepsie, New York 12603, USA
June 9-11, 1982	Fourth Congress of the International Society for Aerosols in Medicine, Czechoslovakia. Details from Czchoslovak Medical Society, J.E. Purkyne, CS-120 26 Praha 2, Vitezneho unora 31, Czechoslovakia.
June 15-16, 1982	The III International Colloquium for the Prevention of Occupational Accidents and Diseases in the Iron and Metal Manufacturing Industry, Palma de Mallorca (Spain).
July 13-16, 1982	Joint Meeting of the Society of Occupational Medicine and Irish Society of Occupational Medicine, Dublin.
August 23-25, 1982	Second International Symposium Epidemiology in Occupational Health Montreal.
September 12-17, 1982	American Chemical Society Symposium on Chlorinated Dioxins and Dibenzofurans in the Total Environment, I Kansas City, Missouri.
August 28- September 2, 1983	American Chemical Society Symposium on Chlorinated Diseases and Dibenzofurans in the Total Environment, II.
September 21-24, 1982	International Symposium on the Protection of Workers against Vibration. Niš (Yugoslavia)
October 14, 1982	World Congress on Diseases of the Chest, Toronto.
October 18-22, 1982	Ontario Occupational Health Nurses' Association Conference, Niagara Falls, Ontario.
October 29-30, 1982	Society of Occupational Medicine Autumn Meeting, London, England.

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